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THE CHICAGO DRAINAGE CANAL, in regard to its effect upon the current and navigation of the Chicago River, is reported upon favorably by Major J. H. Willard, U. S. Engineers, in his annual report. From this it appears, as had been supposed, that the rumors as to the current being so great as to make the river practically unnavigable, are entirely unfounded. The following is an extract from the report:

The observations made to ascertain effects under existing conditions consisted in measuring discharges with current meter at critical points in the Chicago River between the lake and canal, especially at the bridges, where the greatest dangers were to be feared, through as large a range as could be got with safety. The discharges into the canal were measured by meter and by rods for different settings, to compare with estimates and with measurements previously taken in Illinois and Desplaines Rivers. The bridge sites giving the most restricted sections naturally were the places to expect the greatest velocities. They made the most convenient points for measurements. The maximum velocity in Chicago, in miles per hour, for discharges in cubic feet per minute of the Drainage Canal are as follows:

Bridges.	Disch'ge 150,000 to 210,000 feet per hour.	Disch'ge 270,000 to 310,000 feet per hour.
Rush St.	1.28	1.61
Clark St.	1.23	1.64
Wells St.	1.03	1.64
Washington St.	1.46	2.19
Van Buren St.	1.28	1.85
Eighteenth St.	1.14	1.88
Canal St.	1.20	2.24
Halster St.	1.14	1.80

There is no doubt that the reversed current in the Chicago River has increased the difficulty of navigating it with the large boats now demanded by commerce, but it is a noteworthy and gratifying fact, not unexpected by me at least, that the pilots have been quick to adapt themselves to the new condition, and I have little doubt but that they could handle their boats safely even in greater currents than now obtain. If I have not overestimated the pilots' skill, and considering the immense benefit of the Drainage Canal to the city of Chicago since its opening only a few months ago, I recommend that no restrictions be placed upon the legal requirements of flow into the sanitary canal unless it should be found absolutely necessary to do so.

The engineer department, the city of Chicago, and the Sanitary Board are of one mind as to the need of improving the Chicago River, and are co-operating partly to that end, and large sums are being appropriated and expended judiciously by each for the object in view. The interest of navigation not only are being protected, but are being advanced practically sooner than could be hoped for in the usual course.

All interests are agreed as to the immense value of the canal, and the District Commissioners are as anxious to reduce the velocity of the river's current as any engaged in navigation on the river. Congress has indicated that further aid from the United States would depend upon the removal of the center pier and obstructive bridges and the lowering of tunnels, in accordance with the earnest recommendations of Major Marshall for radical improvements of the Chicago River.

Following these hints, the Sanitary District took up the present U. S. Engineer's project on a large scale, and applied to the Secretary of War for permission to widen the Chicago River between Twelfth St. and Ashland Ave. to 200 ft., and to dredge to the depth of 21 ft., constructing new docks capable of withstanding an ultimate depth of 30 ft. This is to be followed by a general reconstruction of bridges, substituting some form of bascule for the center bridges at State, Randolph, Harrison, Polk, Taylor, Eighteenth, Canal and Ashland. The bridge at Taylor St. on the plan approved by the Secretary of War, should be ready for service about Sept. 12. It is hoped that four others may be put under construction this year and the remainder early next season.

THE EYRE-CRAGIN ISTHMIAN CANAL CONCESSION has been proclaimed to have gone into effect by President Zelaya, of Nicaragua, who has also announced the termination of the concession held by the Maritime Canal Co.

THE IMPORTS OF PORTLAND CEMENT into Chili are mentioned in a report of the Belgian Consul at Valparaiso, and, according to the information given, Chili is one of the largest consumers of cement in South America. During the last few years the average quantity of cement imported has reached 100,000 barrels per year. Work on the sewers at Concepcion is now being pursued and it is hoped that the government will soon undertake the building of those at Santiago, an important work which will necessitate the use of large quantities of this product. The yearly imports of the port of Talcahuano amount to from 15,000 to 20,000 barrels; those at Valparaiso from 40,000 to 60,000; those of Valdivia and Iquique from 5,000 to 15,000 barrels each. The importations at the ports of Talcahuano and Valdivia tend to increase owing to the important railway constructions which are being executed in the southern region, particularly the railway from Pitrufquen to Valdivia. Statistics for 1899 not yet having been published only those for the port of Valdivia are obtainable, where 41,199 barrels were unloaded, 27,569 of which came from Hamburg, 11,050 from London and 2,580 from Antwerp. Not one barrel was shipped from the United States.

THE EXPORTS OF MANUFACTURES by the United States during the fiscal year ending June 30, 1900, are summarized by the Treasury Bureau of Statistics as follows for those articles whose value were $1,000,000 or more:

Name of Articles.	1890.	1900.
Iron and steel and mfrs. of...	$25,542,208	$121,858,344
Oils, mineral, refined.....	44,658,854	68,246,949
Copper manufactures.....	2,349,392	57,851,707
Leather, and manufactures of.	12,438,847	27,288,808
Cotton manufactures	9,990,277	23,890,001
Agricultural implements	3,859,184	16,004,886
Chemical, drugs, etc.....	5,424,279	13,196,638
Wood manufactures	6,509,645	11,230,978
Paraffin and pariffin wax.....	2,408,709	8,602,723
Fertilizers	1,618,681	7,218,224
Scientific instruments	1,429,785	6,431,301
Paper and manufacture of....	1,226,686	6,215,559
Tobacco manufactures	3,876,045	6,009,646
Fibers, vegetable, mfrs of....	2,094,807	4,438,285
Cycles	not stated	3,551,025
Books, maps and engravings..	1,886,094	2,941,915
Carriages and horse cars.....	2,056,980	2,809,784
Starch	378,115	2,604,362
Cars for steam railways.....	2,689,698	2,554,907
India rubber and gutta-percha manufactures	1,090,307	2,364,157
Spirits, distilled	1,633,110	2,278,111
Vegetable oils (except cotton and linseed)	326,227	2,162,759
Malt liquors	654,408	2,137,527
Clocks and watches.....	1,635,136	1,974,202
Musical instruments.....	1,105,134	1,955,707
Glass and glassware.....	882,677	1,933,201
Paints and colors.....	578,103	1,902,058
Gunpowder & other explosives.	868,728	1,888,741
Brass manufactures	467,313	1,866,727
Soaps	1,109,017	1,773,921
Marble & stone manufactures.	729,111	1,677,169
Zinc manufactures	156,150	1,668,202
Sugar, refined (excl'dg candy)	2,080,662	1,569,317
Wool manufactures	437,479	1,253,602

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred at Aurich, Ark., on the St. Louis Southwestern R. R., Aug. 6. A passenger and freight train collided, killing five men and seriously injuring two.

THE CHANGE OF MOTIVE POWER on the Manhattan Elevated Ry., of New York city, has been planned in all its details and is rapidly being carried out, according to the "Electrical Review." The power station at the foot of 74th St. is well under way and the construction of the four large chimneys has been commenced. They are to be built of tiles on the Custodis system, and each will be 17 ft. in clear flue diameter and will have a height of 278 ft. above the foundation. The normal capacity of the power house will be 64,000 HP., with a maximum of 100,000 HP., not including the storage battery plants to be placed in the substations. The engines are being built by the Edward P. Allis Co., and the Westinghouse Electric & Mfg. Co. is building the generators. It is expected that the first electrically equipped train will oe ready for use in about six weeks. A motor car will be placed at each end of a six-car train. Each motor car will carry four motors of 100 HP. each, giving the train a total of 800 HP., and making possible an acceleration of two miles per hour per second. Without increasing the number of cars in service, it is expected that the increased acceleration and the possibility of running at higher speed will increase the carrying capacity about 40%. By using more cars the capacity may be doubled. The cars will be electrically heated and lighted and will be provided with electric signaling devices. The first train will be equipped with the air-brake system of the New York Reinforced Air-Brake Co. Three-phase currents will be generated at the central station at 12,000 volts, which will be transformed and converted by the rotaries at the substations to 550 volts direct current. This will be distributed to the cars by a third rail. A special rail has been manufactured by the Lackawanna Iron & Steel Co., having low manganese and carbon content, in order to increase the conductivity. The finished rails give the following analysis: Carbon, 0.073%; Manganese, 0.340%; sulphur, 0.073%, and phosphorous, 0.069%. These rails have a resistance only 7.75 times that of pure copper, while the ordinary running rails of the elevated road show a resistance as high as 11.8 times that of copper. The third rail is shaped like a high T rail and weighs 100 lbs. per yard. Each 60 ft. length is drilled with five holes at each end, three in the web and one in each side of the flange. The tie-plates are to be bolted in one hole and the four other holes are intended for bonds, which will be rigid and very short. At intervals of 300 ft. there will be expansion joints, with flexible bonds. The rail will rest in chairs on the top of solid vitrified tile bells, supported by iron castings to which they will be secured by cement. The running shoes will bear by gravity on the top of the rail. All the stations will be lighted by incandescent lamps, making a total lighting load of about 30,000 lamps. The first section to be equipped will be the Second Ave. line, which is nearest the power house.

STREET RAILWAY SUBWAYS for Chicago have many times been proposed, in order to improve the rapid transit facilities of the business district of the city. These facilities are now very poor owing partly to the congestion of traffic and partly to the wretched condition of the streets. The Union Traction Co., which owns practically all the surface lines on the North Side and West Side has submitted to the municipal Street Railway Commission plans for a system of this kind, providing loop terminals, but with no through lines between the three districts into which the city is divided. This plan, if adopted, would perpetuate the double-fare system, against which there is so much complaint. The plan is approved by the Chicago City Ry. Co., which owns the lines on the south side of the district. The central station would be on Madison St., between State and Dearborn Sts., and this would be reached by the six terminal loops. A fourth tunnel would be built under the Chicago River, at Dearborn St. The subways would be double-track tunnels, with steel side and center columns and 30-in. plate girders for the roofs, with concrete filling for floor, walls and roofs. The width between columns would be 16 ft., height from rail head to roof, 14 ft. A pipe gallery or subway would be formed between the roof of the subway and the surface of the street, the station platforms being 24 ft. below the surface. The cost was originally estimated at $1,000,000 per mile, but with the pipe galleries the cost will be about $2,000,000 per mile, or nearly $20,000,000, including the stations. Practically all the work would be done in open cut, on account of the water and gas pipes, sewers, electric conduits, etc., to be removed and relaid.

THE RAILWAYS OF INDIA aggregated 26,790 miles at the end of March, 1900, showing a net increase of 731 miles since 1899, and the return on the capital was 5.34%, as compared with 5.37% for the previous year. There are about 14,490 miles of 5 ft. 6 ins. (standard) gage, 11,480 miles of meter gage, and 820 miles of special narrow gages. The standard gage line have 3,057 locomotives, 7,780 passenger cars and 55,081 freight cars; while the meter gage lines have 1,480 locomotives, 5,483 passenger cars and 30,305 freight cars. On the standard gage lines, 40.8% of the locomotives are fitted with the automatic vacuum brake, and 11.15% of the cars are braked or piped for brakes. On the meter gage lines, the proportions are only 8.73% and 1.95%. The number of employees on the lines of these two principal gages was 338,859, of whom 5,262 were Europeans, 7,378 East Indians, and 326,219 were natives. There were 3,311 stations on these lines. On the total system of railways there were 863 persons killed and 896 injured. Of these, 67 passengers and 202 employees were killed; while 277 and 431 respectively were injured.

HEAVY LOCOMOTIVES AND FREIGHT TRAINS in England are beginning to be a feature in the freight traffic of that country, in spite of the fact that it has been persistently urged that there is no reason for following American practice in this respect. The Lancashire & Yorkshire Ry. has recently put in service several eight-coupled freight engines for coal traffic, and one of these has hauled 100 empty cars (said to be the largest train ever hauled in England), and 60 loaded cars, the latter train aggregating over 1,000 tons. The former engines hauled an average of 27 loaded coal cars. The engines have inside cylinders, long straight-top boilers, with the dome on the middle, and long fireboxes. There is no truck. The engines have the usual six-wheeled English type of tender. The engines were designed by Mr. J. A. F. Aspinall, General Manager, who was formerly Superintendent of Motive Power. The leading dimensions are as follows:

Driving wheels		4 ft. 6 ins.
Wheelbase		16 " 4 "
Weight of engine		120,484 lbs.
Weight of tender, loaded		68,684 "
Cylinders		20 x 26 ins.
Boiler, diameter		4 ft. 10 "
Firebox		7 ft. 6 ins. x 3 " 6 "
Tubes, 239; diameter, outside		2 "
Tubes, length		15 ft.
Heating surface,	tubes	1,877 sq. ft.
" "	firebox	162 " "
" "	total	2,039 " "
Grate area		26 " "

THE DRAINAGE OF THE CITY OF NEW ORLEANS.

(Continued from p. 184, Vol. XLIII.)

By L. W. Brown, M. Am. Soc. C. E.

(With two-page plate.)

Lined and Covered Canals.—The large volume of immediate run-off reaching the canals, requiring large section, combined with level territory, unstable soil and the desirability of securing minimum lift at the pumping stations, precluded the usual brick sewer construction and necessitated the rectangular section with brick arches supported by steel I-beams, to form the cover of the conduit and a base for the roadway of the street. The form of retaining walls and cross-section of canals, as originally designed and determined upon in 1895, was modified by the Drainage Commission, as seen in Figs. 7 and 8. Fig. 9 is a section of the St. Louis Street canal, maximum dimension, and Fig. 10 is a section of the Chartres Street canal, showing minimum dimension. These sections show the relative width of street, location of canal and the character and proximity of adjacent improvements.

As will be seen, the detail of construction of the conduits varied with their dimension and the relative integrity of the soil in which they were placed. Where the soil did not have sufficient integrity, the whole structure was supported on piling placed as shown in Fig. 9. Generally, all conduits having a greater width than 18 ft. were placed on piling. Where no piles were placed, planking was laid directly on a properly excavated sub-grade, on which was laid a block of concrete forming the channel and supporting the retaining wall, as shown in Fig. 10. The retaining walls were made perpendicular on the back and battered on the side towards canal, as shown in Figs. 9 and 10. This slope was 0.285 ft. per ft., and was formed by specially molded brick; the bottom was surfaced with cement mortar and polished, thus providing the greatest possible value to co-efficient n.

The canals now constructed vary from a maximum of 25 ft. wide and 9 ft. deep below flood slope, or 13 ft. below surface of street, with a delivery area of 170 sq. ft., to a minimum of 5 ft. wide and 7 ft. deep below flood slope, or 11 ft. below surface of street, with a delivery area of 16 sq. ft.

The excavation required for the construction of the canal varied from 15 cu. yds. per running foot, for maximum section, to 2½ cu. yds. per running foot for minimum section; and the total amount of work now completed is 24,480 lin. ft., or 4.636 miles. The average detail dimensions are as follows:

Name of canal.	Average: Excavation per lin. ft., cu. yds.	Average: Width of finished canal at flood slope, ft.	Average: Depth from flood slope to finished bottom, ft.	Average: Depth Surface of street to finished bottom, ft.	Average: Average available area for flow sq. ft.
St. Louis	14.0	22.5	8.45	13.5	149.1
Basin	9.4	16.16	7.67	12.2	100.6
Julia	5.6	9.67	6.00	9.7	43.2
Constance	4.0	6.33	4.00	8.7	21.0
Canal	5.1	9.33	6.67	9.4	44.2
Camp	2.5	5.25	4.58	7.4	16.4
Chartres	3.0	5.5	4.50	8.0	17.0
Claiborne	5.0	7.75	6.50	10.5	38.8

As will be observed, these canals were located in the most thickly settled commercial portion of the city; the streets were narrow, and heavy buildings stood directly on the property line. There were also a great number of large and small gas and water pipes to be rearranged and removed from the line of conduit; and large numbers of street railway tracks, operated by electricity, had to be crossed or paralleled. The work in connection with these street railways was so arranged that it was executed without suspending or interfering with their usual operation. The longest period that the cars were delayed did not exceed three minutes, and such a delay occurred but a few times on the whole work.

The soil in which the work was executed was very diversified in character, the larger portion of the work occupying a location which was originally covered by cypress swamps, with immense stumps, buried 3 or 4 ft. below the surface of the street; large deposits of quicksand were also encountered; other portions passed through a shifting or moving sand material, and others were in clay. The stumps which had to be removed from the line of excavation were in such proportion to the whole excavation that it might be said we excavated them by the cord instead of by the yard.

The brickwork of the bottom half of the retaining walls in the large canals was laid in mortar composed of 1 part Utica (natural) cement and 2 parts sand; and the upper half of the wall was laid in mortar composed of 1 part Steel Portland cement (Illinois Steel Co.) and 3 parts sand. The concrete used was made of small, hard, clean lake clam shells and Steel Portland cement in proportions of 1 part cement and 3 parts sand, with sufficient shells to admit of all interstices being thoroughly filled with the mortar.

Fig. 11 is a sketch showing the arrangement of tracks and machinery and the method adopted for the execution of the work on St. Louis St., which is 54 ft. wide, and where the excavation was 33 ft. wide. Fig. 12 shows the arrangement adopted in the construction of a similar canal placed to one side of the center of street, the canal paralleling a street car track placed in the center.

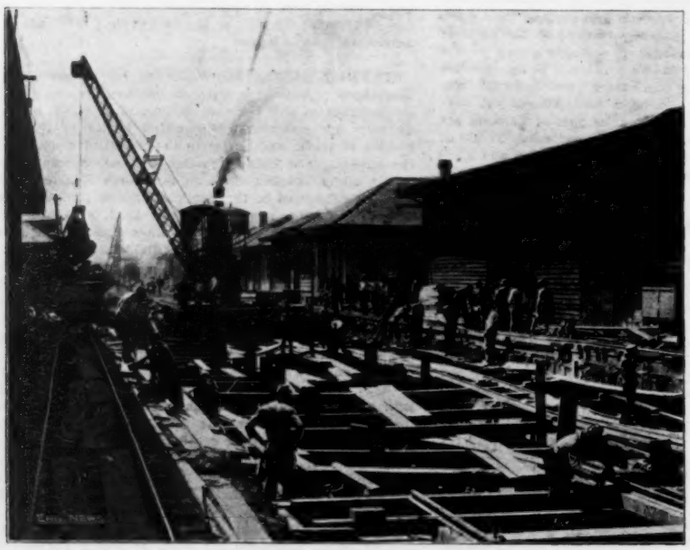


FIG. 18.—VIEW OF WORK ON ST. LOUIS CANAL, SHOWING EXCAVATING MACHINE DUMPING BUCKET INTO SKIPS.

FIG. 19.—WORK IN PROGRESS ON CHARLES ST., 38 FT. IN WIDTH.

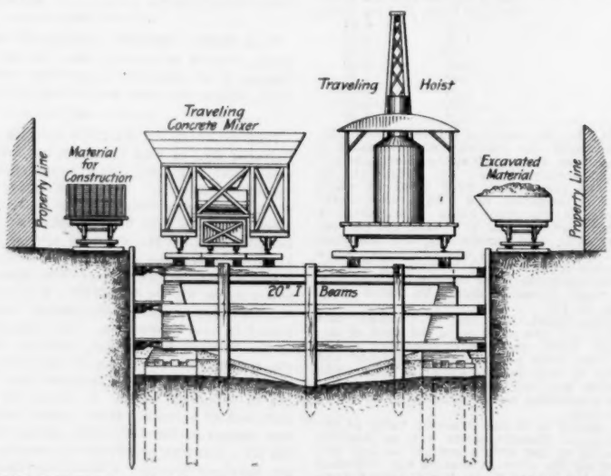


FIG. 15.—CROSS-SECTION ON ST. LOUIS ST. CANAL, SHOWING ARRANGEMENT OF MACHINERY DURING CONSTRUCTION.

sheet-piling was driven on the line of extreme excavation; this sheet-piling being in the main 4 ft. wide and extending 5 ft. below the lowest point of excavation. This sheet-piling was driven by the same driver and at the same time that the piles for the foundation were driven—where these were required, and the work was done by a No. 2 steam hammer mounted on a car running on a track of 8-ft. gage. The pile driver was placed on a turntable so arranged as to make a complete circle, as shown in Fig. 13. The excavation was made by a 10-ton Brown Hoist traveling derrick, arranged with double drum and levers to operate a four-part ¾-cu. yd. Hayward bucket, with a boom controlling a radius of 45 ft. This excavating machine was operated on a track constructed ahead of the excavation, and it delivered the excavated material into skips placed on cars, operated on a track placed alongside of the excavation, as shown in Figs. 11 and 12. The skips were built of steel, shaped as shown in Fig. 14, and had a capacity of 2 cu. yds., water measure; they were provided with a trunnion on each side and a ring in the end for the purpose of attaching a tripping bridle for lifting and dumping. The excavated material was conveyed to a spoil-bank (the average haul being about 2½ miles) by means of an electric overhead trolley. The gage of the tracks was 30 ins., and the cars were of the skeleton platform type, made with a rolled steel frame, on which the skips rested. Each car would carry three skips, and the trains usually consisted of four cars, hauled to the spoil-bank by a motor car operated by two G. E. 800 motors attached to each axle of the truck by sprocket-chain gearing; the trolley pole was bent so that the trolley wire was carried 5 ft. from the center of track, to admit of the excavator dumping directly into the skips. At the spoil-bank was located a three-ton American Hoist traveling derrick; and as each of the loaded cars came under it, a tripping bridle was attached to a skip, which was then hoisted and swung around by the derrick to any desired point on the spoil-bank; the trip was pulled, the skip dumped, the trip of the bridle was refastened and the empty skip placed back on the car; this process was repeated until the whole train was unloaded.

A gang of graders was placed in the bottom of the excavation grading and preparing the foundation, throwing the surplus material ahead where it could be reached by the Hayward bucket; and as fast as the excavation was made and the bottom graded the temporary bracing was placed between the sheet-piling forming the sides of the excavation. The rangers against the sheet-piling were 8 × 8 ins.; the bracing resting against these rangers was of 8 × 8 ins., and these were forced into position by 2 × 10-in. jack screws; there were generally three braces in each bay and the bays were placed 6 ft. apart. To the braces were spiked 2 × 6-in. uprights, forming a support; and the braces were tied laterally by 2 × 6-in. pieces, running longitudinally, the number of laterals depending on the width of the canal; though usually three were used. The general arrangement of construction of this bracing is shown in Fig. 15.

On top of the bracing, above described, was placed the small tramway on which ran the small concrete cars for delivering the concrete from the mixer on to the sub-grade, or the mortar to the mortar boxes when the walls were being constructed. The concrete mixer was arranged to run on a track of 8-ft. gage, and was moved along and kept up with the work so as to be located generally somewhere near the end of the completed brickwork. The general and detail arrangment of this mortar and concrete mixer and the small dump cars are shown in Fig. 16. The mixed concrete or mortar was dumped from the mixer into small side dump cars, which cars had a capacity of 18 cu. ft., and run on a light track to the point where the concrete was wanted and dumped. The concrete mixer consisted of a heavy cast-iron box in which revolved, in opposite directions, paddles of considerable pitch, attached to a heavy shaft. The dry material was shoveled into hoppers, which were gaged, and the contents of these several hoppers were dumped directly into the mixer by means of doors operated by levers. The mixer was provided with a bottom dump, which was operated by a lever, and as the concrete was mixed it was dumped into the small dump cars underneath. The mixer was found to be most advantageously operated by dumping the sand and cement in together, mixing it dry and then turning on water, and letting down the shells. All of these materials were delivered on the work from the material yard in skips, similar to those used for excavating, and they were lifted from the cars and dumped on to the platform by a 3-ton American Hoist traveling derrick, which, as the skips were dumped, would replace them on the cars. This 3-ton American Hoist traveling derrick was placed directly over the completed part of the canal and was utilized for lifting the cement, sand and shells onto the platform of the concrete mixer, for the lifting the bricks from the material cars directly into the canal excavation, and for lifting the large beams, which in the large canal weighed upwards of one ton each, from cars on the material track and placing them in position. The material was delivered from the material yard to the canal on cars operated by a trolley; and this material track was placed directly alongside of the work and was extended as the work progressed. The material yard was some 1,500 ft. long and about 60 ft. wide; at this yard all the material was received, and it was connected by a switch with the trunk railway lines. The cement was delivered directly from the large railway cars into the cement warehouse, located directly alongside of the narrow gage material track, and from this house the cement was loaded into skips and taken on to the work as wanted. All of the sand, shells and brick were delivered by barges, with a capacity of about 250 cu. yds. each; they were delivered alongside of the landing and were unloaded by means of a 10-ton Brown Hoist traveling derrick, having a boom of 45-ft. radius and operating a one-yard clam-shell bucket, which lifted the sand or shells from the barges to the large bins on the landing, and also from the bins into skips placed on cars on the narrow-gage material tracks, for delivery to the work as wanted. The track on which the traveling derrick operated extended the whole length of the landing.

As the bricks were taken from the kiln across Lake Ponchartrain, where they were burned, they were piled on crates (shown in Fig. 17), each crate having a capacity of 1,000 bricks, and these crates with the bricks were picked up by a derrick, placed at the kiln and loaded directly into the barges; each barge having a capacity of about 100,000 brick. The barge would be towed directly alongside of the landing, where the traveling derrick would lift the crates by a yoke and deliver them onto the landing, or would deliver them from the landing onto the material cars. Each car carried four crates, and as they were delivered on the work the American Hoist derrick, traveling on top of the finished canal, would lift these crates directly into the canal where the masons could reach them; the two hooks of the yoke would be detached, the bricks dumped and the crates hoisted back, placed on the cars and returned to the landing, where they would be loaded on the barges and sent back to the kiln. This method of handling bricks proved extremely satisfactory, saving not only a very great amount of expense and time, but very materially reducing the percentage of breakage.

On the canals of large section the maximum amount of work dore in one day was the entire completion of 57 lin. ft. of canal, which aggregated 813 cu. yds. of excavation, 124 cu. yds. of brickwork, 116 cu. yds. of concrete, 127 sq. yds. of bottom surfacing This included the setting of I-beams, building arches, placing and removing bracing, back filling, etc.

On the canals of small section the maximum amount of work done in one day was the entire completion of 213 lin. ft. of canal, which aggregated 544 cu. yds. of excavation, 129 cu. yds. of brickwork, 154 cu. yds. of concrete, 115 sq. yds. of bottom surfacing. This included, as before, the setting of I-beams, building arches, etc.

Open and Unlined Canals.—This work consisted of the deepening and enlarging of existing canals which were located in the unimproved portions of the city. The work was performed by a floating

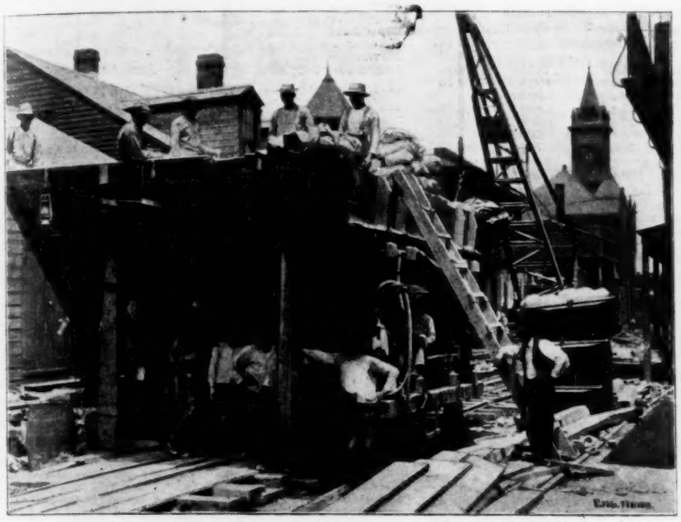


FIG. 20.—CONCRETE-MIXER ON BASIN ST.

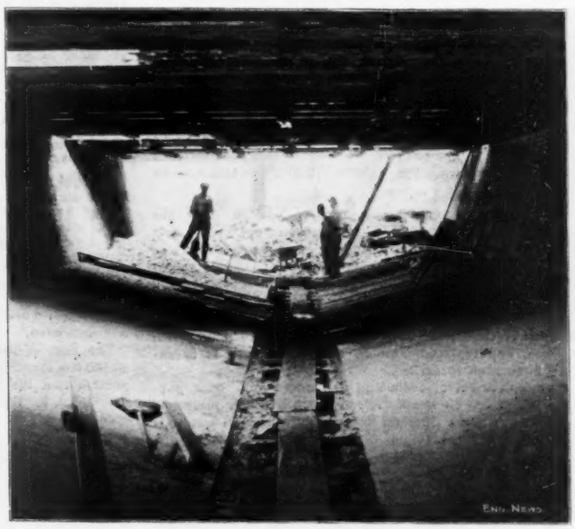


FIG. 21.—INTERIOR VIEW OF THE ST. LOUIS CANAL, SHOWING SMOOTH CONCRETE INVERT.

dipper dredge, depositing the excavated material directly on the bank of the canal. The work aggregated about 305,000 cu. yds., was performed in the following canals: Orleans relief canal, Pumping Station No. 7, to Hagan Ave., 9,500 lin. ft.; Metairie relief canal, Pumping Station No. 6, to 17th St., 3,900 lin. ft.; Dublin canal, from 17th St. to Claiborne St., 4,900 lin. ft.; Claiborne canal, from Dublin St. to Nashville Ave., 5,900 lin. ft. Total, 24,200 lin. ft.

(To be continued.)

OPERATION OF THE WATER SETTLING AND FILTRATION PLANT AT ALBANY, N. Y.

We take great pleasure in presenting to our readers the results of nearly a year's operation of the water purification plant at Albany, N. Y. The period covered is 319 days of actual operation, during which a total of 3,817,200,000 gallons of water were filtered, or an average of nearly 12,000,000 gallons a day. This is the largest amount of water ever filtered by a single American filtration plant in so short a period. The information presented was very kindly supplied to us by Mr. Geo. I. Bailey, M. Am. Soc. C. E. Mr. Bailey's reason for not including the additional 26 days needed to bring the record up to a full year are stated in the opening paragraph of his notes, explaining and summarizing the tables. These notes are as follows:

The period of time chosen is from July 26, 1899, the day the first filter bed was put in operation, up to July 1, 1900. This period represents a cycle in operation, as the plant is nearly in the condition it was before operation commenced, and in the interval of 319 working days has performed all of its functions, viz.: 3,817,200,000 gallons of water have been filtered; the beds have been scraped 77 times; the scraped material has been removed, washed, and replaced, and all labor and material necessary have been furnished.

A complete set of tools and appliances have been purchased and are on hand. A fair stock of other materials is on hand; a few bills for material are unpaid, but it is believed the value of the former will offset that of the latter.

The cost of operating the filter beds and the care of the grounds (Table I.) has been $1.94 per 1,000,000 gallons, which is well under $2.50, the engineer's estimate. (Cleaning the settling basin costs 5 cts. per 1,000,000 gallons additional.—Ed.) The cost for chemical and bacteriological work is $0.34 per 1,000,000 gallons, which was not estimated.

The cost of pumping is $2.42 per million, which was estimated to cost $1.50. This excess is nearly in the proportion that the pumping plant fails below the efficiency demanded by the contract. This increase is also partly accounted for by the increased cost of coal, oil and supplies.

The efficiency in bacterial removal (Table III.) has been good. In January and February we had not learned to make the rate on newly scraped filters conform to the turbidity of the raw water, and the number of bacteria in the effluent shows the result of our ignorance. With present knowledge it would seem that there is no occasion for these large counts to be repeated. The influence of rate on bacterial removal is indicated in the table showing the daily operation of each filter, under date of June 8, where filter No. 5, which had just been refilled with sand, was started at a 6,000,000-gallon rate, through the negligence of a newly appointed watchman.*

The immediate and quick returns in the decrease of typhoid fever (Table IV.) is as unusual as it is gratifying. There have been fewer cases of typhoid fever than there were deaths from this cause before. The location in Albany of one of the best hospitals in the state, which draws to it patients from a large and populous district, increase unduly the death rate for this city, by crediting to it the mortality of aliens. During the year typhoid in

*The table in question is not reproduced, as it would fill about three of our columns. On the date named there were 2,400 bacteria per cu. cm. in the raw water and 495 in the filtered water, a reduction of only 80%. On the second day after, with 2,850 bacteria in the raw water the effluent showed only 105 germs, the reduction having increased in two days to 96.3%.—Ed.

TABLE I.—Cost and Labor Involved in Operating and Maintaining Water Filter Plant, at Albany, N. Y., from July 26, 1899, to June 30, 1900, inclusive.

(Days operated, 319. Received from filters 3,817,200,000 gallons.)

Filter:	Labor	$5,107.62
	Superintendence	1,392.58
	Tools and supplies	377.75
	One-half cost of miscellaneous items	304.75
	Wash water for sand at 1 ct. per 100 cu. ft	209.06
	Total	$7,391.76
Cost per 1,000,000 gallons		$1.94
Cleaning sedimentation basin, per 1,000,000 gals		.05
Pumping:	Engineers and firemen	$4,258.65
	Laborers' services	387.00
	Coal and supplies	3,497.84
	Oils, packing, gaskets, soap, light, lesser items	799.06
	One-half cost of miscellaneous items	304.75
	Total	$9,247.30
Cost per 1,000,000 gallons		$2.42
Laboratory:	Chemist,	$999.96
	Laborers' services	69.38
	Laboratory supplies	245.15
	Total	$1,314.49
Per 1,000,000 gallons		$0.34
Gross cost per 1,000,000 gallons		$4.75

Analysis of Operation of Filter Beds.

	Time required	Per cent. of total.	Cost	Av. per 1,000,000 gals.
	Hours.		Total.	
Labor: Scraping	3,231	13.21	$948.97	$0.75
Wheeling out	6,488	26.53	1,905.83	
Washing sand	6,328	25.87	1,858.42	.54
Refilling	5,104	20.87	1,499.24	.39
Cleaning basin.	716	2.92	209.76	.06
Incidentals*	2,593	10.60	761.47	.20
Total	24,460	100.00	$7,183.69	$1.94
Materials: Water for wash'g sand			$209.06	$0.05
Total cost, sedimentation and filtration, exclusive of pumping and laboratory				$1.99

*Items 4 and 5 under "Filter," above.

TABLE II.—Operation and Yield of Each Filter Bed.

Filter No.	No. of scrapings.	Hours run.	No. gallons filtered.
1.	9	5,864	458,000,000
2.	11	6,425	480,000,000
3.	10	5,725	449,000,000
4.	11	6,330	478,000,000
5.	9	5,705	430,000,000
6.	10	5,929	479,000,000
7.	7	4,451	395,000,000
8.	10	6,127	472,000,000
Total	77	46,556	3,571,000,000

Average run = 604.6 hours, yielding 46,387,000 gallons.

Average run = 25.19 days, yielding 66,268,000 gallons per acre.

Daily average per acre = 2,631,000 gallons.

TABLE IV.—Typhoid Fever Death Records at Albany, N.Y., Before and After Introduction of Filtered Water.*

Months.	Water—Unfiltered.—Average for 9 yrs.	Water—Unfiltered.—1899.	Water—Filtered.—1899.
January	11	14	..
February	10	12	..
March	12	14	..
April	8	13	..
May	4	3	..
June	4	9	..
July	4	2	..
August	8	4	..
September	6	..	2
October	4	..	4
November	6	..	0
December	8	..	1
Total	85	71	7†

*Portions of the supply are still from gravity sources, unfiltered.

†Physicians report one case contracted out of city.

‡Physicians report six cases contracted out of city.

TABLE III.—WEEKLY SUMMARY OF OPERATIONS OF ALBANY, N. Y., FILTER PLANT.

Week ending.	[1]Scraping beds, hrs.	Wheeling out scrapings[2] B'row Hrs.	B'row loads.	Washing sand.[3] B'row Hrs.	B'row loads.	Refilling beds with sand.[4] B'row Hrs.	B'row loads.	Hours labor, [5]Engine room	Laboratory[6]	Incidentals[7]	Lost time[8]	Total.	Cost Labor.[9]	Superintendence.	Chemist.	Total.	Gallons filtered, 1 = 1,000.	Bacteria, per cu. cm. Hudson R. water Raw.	Filtered.	Unfiltered water Removed, %	Rensselaer Lake.	Bleecker.	Prospect Hill.	Tivoli.
Aug. 12, '99	122	...	.....	...	.....	...	.....	...	...	...	...	122	$50.26	$19.00	.....	$69.26	167,980	.....	.....	.....	.....	.....	.....	.....	.....
" 19....	127	...	.....	...	.....	...	.....	3	6	...	...	136	27.75	29.75	$166.66	224.16	.....	.....	.....	.....	.....	.....	.....	.....	.....
Sept. 2....	...	375	3,616	...	.....	...	.....	10	...	11	...	396	103.87	52.75	.....	156.62	.....	.....	.....	.....	.....	.....	.....	.....	.....
" 9....	...	163	1,625	...	.....	...	.....	12	12	11	...	198	60.94	24.50	.....	85.44	55,724	11,545	608	94.8	.....	.....	.....	.....	.....
" 16....	57	91	1,028	55	362	...	.....	64	10	141	...	418	85.87	24.50	.....	110.37	104,564	14,083	306	97.8	.....	.....	.....	.....	.....
" 23....	...	...	.....	269	1,737	...	.....	91	10	34	...	404	85.50	24.50	.....	110.00	97,626	17,480	273	98.5	.....	.....	.....	.....	.....
" 30....	110	106	1,929	58	337	...	.....	14	4	6	...	358	90.00	24.50	83.33	197.83	76,057	22,600	259	98.8	.....	.....	.....	.....	.....
Oct. 7....	152	241	2,618	18	94	...	.....	7	14	26	...	458	90.00	24.50	.....	114.50	85,639	18,766	250	98.7	.....	.....	.....	.....	.....
" 14....	50	80	813	289	2,155	...	.....	7	15	12	...	453	87.00	24.48	.....	111.48	88,228	11,783	178	98.5	.....	.....	.....	.....	.....
" 21....	49	75	875	295	2,474	...	.....	11	11	9	...	410	84.00	24.48	.....	108.48	84,221	9,933	85	99.1	.....	.....	.....	.....	.....
" 28....	146	238	2,339	27	237	...	.....	7	11	28	23	480	87.38	24.48	83.33	195.19	87,069	4,733	84	98.4	.....	.....	.....	.....	.....
Nov. 4....	71	162	1,682	164	1,545	...	.....	...	...	...	...	397	90.00	24.48	.....	114.48	84,175	6,691	56	99.1	350	310	378	650	.....
" 11....	45	81	789	107	1,476	...	.....	8	10	8	164	483	84.22	24.48	.....	108.70	87,744	5,141	46	99.1	650	160	160	750	.....
" 18....	61	82	726	216	2,103	...	.....	15	13	51	39	477	81.21	24.48	.....	105.69	86,155	7,950	69	99.1	512	175	180	1,750	.....
" 25....	71	150	1,713	94	1,018	106	1,068	6	7	12	35	481	87.00	24.48	83.33	194.81	88,410	11,090	79	99.3	527	210	221	2,100	.....
Dec. 2....	82	161	1,705	52	549	276	2,963	4	8	10	96	689	129.00	24.48	.....	153.48	73,408	19,240	109	99.4	...	...	...	...	.....
" 9....	43	83	802	187	1,893	684	8,403	12	8	36	65	1,118	209.63	24.87	.....	234.50	77,243	20,016	198	99.1	1,585	300	210	4,108	.....
" 16....	...	...	.....	220	2,282	565	6,116	63	8	57	4	917	179.63	24.48	.....	204.11	83,129	57,700	142	99.7	685	280	280	5,120	.....
" 23....	44	88	920	...	.....	...	.....	192	16	80	61	481	85.50	29.73	.....	115.23	88,535	66,000	327	99.5	4,700	320	350	7,500	.....
" 30....	87	179	1,999	...	.....	...	.....	82	9	52	80	489	88.50	29.73	83.33	201.56	95,904	48,940	215	99.6	675	335	365	3,500	.....
Jan. 6, 1900	42	30	318	...	.....	...	.....	190	8	126	84	480	93.75	29.68	.....	123.43	98,649	44,600	319	99.3	2,882	830	720	3,400	.....
" 13....	78	208	2,038	...	.....	...	.....	56	7	67	56	472	81.00	29.68	.....	110.68	104,264	46,100	618	98.7	3,212	2,500	1,727	5,830	.....
" 20....	122	230	2,271	...	.....	...	.....	13	8	28	80	481	87.75	29.68	.....	117.43	104,609	46,100	861	98.1	3,900	3,200	3,400	4,900	.....
" 27....	137	339	3,513	...	.....	...	.....	21	6	28	50	581	99.60	29.68	83.33	212.61	88,979	107,100	2,493	97.7	20,000	6,000	8,250	33,000	.....
Feb. 3....	83	196	2,072	...	.....	...	.....	31	7	122	74	513	86.82	29.68	.....	116.50	91,098	107,800	1,753	98.4	12,700	3,700	2,500	4,250	.....
" 10....	44	87	947	...	.....	...	.....	170	17	125	37	480	90.00	29.68	.....	119.68	87,855	123,500	320	99.7	12,800	850	2,500	23,200	.....
" 17....	44	86	947	...	.....	...	.....	100	9	129	112	480	90.00	29.68	.....	119.68	87,485	156,200	1,462	99.1	25,000	5,350	12,200	40,000	.....
" 24....	42	85	993	...	.....	...	.....	162	5	86	100	480	103.50	29.68	83.33	216.51	88,768	85,100	941	98.9	25,000	7,700	5,300	43,000	.....
Mar. 3....	87	171	1,974	...	.....	...	.....	78	7	81	56	480	84.75	29.68	.....	114.43	86,744	103,200	533	99.5	12,000	12,200	5,200	27,000	.....
" 10....	138	179	2,042	...	.....	...	.....	54	5	76	46	498	88.17	29.68	.....	117.85	84,365	47,600	414	99.1	14,000	4,650	2,210	32,000	.....
" 17....	43	191	2,079	...	.....	...	.....	64	6	100	76	480	86.25	29.68	.....	115.93	101,497	24,300	467	98.1	9,900	900	1,300	14,000	.....
" 24....	85	177	1,903	...	.....	...	.....	76	9	114	20	481	86.63	29.68	.....	116.31	83,706	46,500	496	98.9	17,200	790	1,420	33,100	.....
" 31....	85	172	2,011	...	.....	...	.....	54	10	123	52	496	92.83	29.68	83.33	205.84	82,050	30,900	252	99.2	5,600	720	430	12,000	.....
April 7....	128	261	3,045	...	.....	...	.....	4	7	44	60	504	94.50	29.68	.....	124.18	81,485	39,000	106	99.7	2,400	370	560	9,500	.....
" 14....	40	90	1,083	338	3,098	...	.....	33	7	19	128	655	109.88	29.68	.....	139.56	84,982	26,100	85	99.7	1,200	275	320	7,200	.....
" 21....	78	182	2,024	292	2,825	...	.....	48	6	69	47	722	137.26	29.68	.....	166.94	81,044	30,100	67	99.8	620	198	192	1,625	.....
" 28....	79	175	2,017	269	2,513	...	.....	2	8	57	30	620	117.94	29.68	83.33	230.95	69,926	12,250	67	99.5	260	165	180	470	.....
May 5....	34	81	871	528	5,050	...	.....	12	5	22	164	746	132.37	29.68	.....	162.05	75,417	4,150	42	99.0	580	190	138	580	.....
" 12....	65	171	1,830	326	3,258	...	.....	22	6	28	30	648	129.57	29.68	.....	159.25	66,191	1,740	26	98.5	320	117	128	410	.....
" 19....	68	216	2,743	203	2,439	324	3,517	16	5	28	55	915	178.57	34.18	.....	212.75	57,398	2,500	41	98.4	180	115	105	250	.....
" 26....	100	246	2,646	608	6,356	686	7,722	12	7	99	11	1,769	342.84	45.43	83.33	471.60	70,807	2,382	60	97.5	390	280	138	1,200	.....
June 2....	66	133	1,629	423	4,766	494	5,864	1	11	13	3	1,144	221.17	45.43	.....	266.60	79,922	3,510	35	99.0	320	155	125	530	.....
" 9....	103	166	2,784	568	5,873	350	4,094	16	7	448	32	1,669	331.27	45.43	.....	376.70	76,914	4,108	56	98.6	360	115	228	250	.....
" 16....	61	107	1,458	278	3,399	594	7,206	45	9	424	14	1,532	301.62	46.93	.....	348.55	78,402	2,840	53	98.1	510	208	98	520	.....
" 23....	30	47	677	308	3,895	867	10,793	56	8	81	12	1,469	287.05	52.93	.....	339.98	93,055	2,400	33	98.6	400	180	94	520	.....
" 30....	32	47	638	56	477	149	1,934	120	8	188	...	600	122.64	29.68	83.33	235.65	99,123	2,430	40	98.4	375	160	110	408	.....
Total....	3231	6488	71,702	6328	62,211	5104	59,390	2,064	370	3300	1896	28,790	$5564.99	$1392.58	$999.96	$7957.53	3,817,246	.....	.....	.....	.....	.....	.....	.....	.....

[1]An aggregate of 77 beds were scraped, having an area of 3,402 sq. yds. each, making 261,954 sq. yds., or 54.12 acres. [2]Add 40% to quantity of washed sand to obtain amount of material wheeled out. [3]The total quantity of sand scraped from Dec. 17 to April 7, inclusive, amounted to 3,687 cu. yds., after washing. [4]Total refilling, Dec. 17 to May 12, inclusive, 3,487 cu. yds. [5]This should be deducted from "operation" cost and added to "pumping" cost. [6]Deducted from same cost, but add to "laboratory" cost. [7]Includes 716 hours for cleaning sedimentation basin. [8]Due to absence, rain, holidays, etc., part of which is paid for and part not. [9]Labor, 18½ cts. per hr.

this city (had it not been for the filter plant.—Ed.) would have been largely increased, owing to the epidemic at Cohoes, a city of 25,000, located eight miles up the river. This is shown unmistakably in the increased death rate from the disease in the city of Rensselaer, located directly across the river from Albany, and whose water supply is taken from the Hudson River.

The determinations made by the chemist in charge may be summarized as follows:

Color.—The color of the raw water varies from about 0.30 to 0.40. When the color of the raw water is 0.40, in the effluent of the filter it is about 0.30. When the color of the water is 0.30, the color in the effluent is about 0.25.

Turbidity.—All examinations are made by the platinum water scale. The average for the six months is about 0.10. The greatest turbidity was in February, when it was 0.90. When the turbidity of the raw water is 0.10, the effluent is practically clear. When the turbidity in the raw water is greater than 0.10, there is a slight haziness in the effluent.

Bacilli Coli Communis.—Examinations to identity coli communis were started May 9, 1900. Twelve samples of the raw water have been taken in all, and in each of the samples taken, from two to ten colonies were found. Of the effluent from the filters 18 samples were taken, in only one of which was coli found, and only one colony of this.

As we have often remarked, actual numbers, as well as percentages, must be considered when judging the work of filter beds. The daily bacterial records of the eight beds for the first six months of the present year (not reproduced here) shows very irregular comparative results for the various beds during the early part of the year, reasons for which are assigned by Mr. Bailey, just above. In April, May and June, all the beds were working on a far more uniform basis. For the first three months of 1900, the average number of bacteria in the filtered water, for the whole plant, never fell below 200 per cu. cm., reaching that figure on March 30. On 16 out of 72 days, the average results for the whole plant during January, February and March, exceeded 1,000 bacteria per cu. cm. (For weekly averages, for the whole plant, see Table III.) But since April 1 the record is far different. On only 2 out of 76 days on which analyses were made during the second quarter of the year, did the bacteria in the effluent exceed 100 per cu. cm. (average for the whole plant). The excess figures were 165 and 126, on April 2 and 6, respectively, when the bacteria in the raw water numbered 45,000 and 37,000, respectively, and when 99.7% of the total were removed, in each case. The results by beds for these three months were also good, and fairly uniform, the excess numbers being, for the most part, during the first week in April, which really belongs to the winter period of relatively poor results.

Most of the other excess numbers followed directly after scraping or refilling the beds. The number of bacteria in the effluent from each bed, in May, June and July, 1900, exceeded 100 in:

Bed No.1..	3 days out of	69	Bed No.6..	1 days out of	70
Bed No.2..	7 " " "	65	Bed No.7..	3 " " "	70
Bed No.3..	11 " " "	54	Bed No.8..	1 " " "	65
Bed No.4..	6 " " "	59			
Bed No.5..	4 " " "	47	Total.....	36 " " "	490

The excess figures were above 200 only twice, when they were 322 and 208, for beds Nos. 1 and 2, respectively, both early in April.

Since the above was put in type we have secured the following additional information from Mr. Bailey, relating to Table III.:

Scrapings Removed.—71,702 barrows ÷ (3,687 cu. yds. washed sand + 40%) = 13.8 barrows per cu. yd.

Refilling.—59,590 barrows ÷ 3,487 cu. yds. replaced = 17.1 barrows per cu. yd.

Rensselaer Lake is unfiltered water, with very large sedimentation. Tivoli is unfiltered stream water with moderate sedimentation. Bleecker reservoir receives two-thirds filtered water by pumps and one-third Rensselaer Lake water by gravity. Prospect Hill ordinarily receives filtered water entirely, but owing to repairs to pumping engines, from about the middle of February until the first part of May we were obliged to take about one-third of its supply by pumping from the mixed water in Bleecker reservoir. From Tivoli reservoir, owing to failure of streams, from about the first of May we have contributed greater or less amounts of the mixed water from Bleecker reservoir to help out this service.

THE PHOTOMETRY OF THE ARC.*

If one compares the results obtained by different investigators on the luminous intensity of the arc, he finds large discrepancies. Indeed, so discordant are the results that the opinion has been advanced by some that such measurements are almost worthless, and that any attempt to obtain consistent and reliable data on the luminous intensity of the arc might well be abandoned at the outset. This is undoubtedly an extreme view, and, personally, I do not share it. We have to consider the question: With what degree of accuracy shall we be content? Anything comparable with the accuracy to be obtained in purely electrical measurements is not to be thought of. On the other hand, that the results from different tests should be concordant to a degree no better than 50% would seem to indicate either that such tests have been made under widely different conditions—that is to say, as to carbons, globes, etc.—or that sufficient time and study have not been bestowed on the methods employed. I am of the opinion that an absolute accuracy of less than 10% and a relative accuracy in any one series of tests of less than 5% are quite within the range of possibility.

It is apparent that the difficulties met in the pursuit of good results in arc-light photometry may be classified under two heads: (1) Those peculiar to the source, and (2) those peculiar to the method.

Of the first class, none is more troublesome than the great change in the intensity in any given direction, due to the wandering of the arc over the surface of the carbon tips. For instance, if the arc shifts suddenly from the remote side of the carbons to the side towards the photometer, the resulting change in luminous intensity may be 200%. Under these circumstances, the only hope of getting a value representing the mean intensity, at least with the use of one photometer arranged in the ordinary way, lies in taking a relatively great number of readings referred to time, and in integrating the result. To accomplish this, I have employed a device to record the settings mechanically. While this is a labor-saving device, it does not obviate the necessity of taking many settings, nor lessen the number of computations. Since taking up the work for your committee, I have constructed a piece of apparatus that greatly reduces the fluctuation in the illumination on the photometer disk, and hence gives a good result with a greatly diminished number of settings. The method involved may be well designated as the double-mirror method, and is, so far as I know, new.† It consists in nothing more than the employment of two mirrors instead of one, and in taking light simultaneously from opposite sides of the arc at the same inclination to the vertical, both mirrors being capable of ready adjustment at any angle in the vertical plane. The arrangement of apparatus for carrying out this plan is shown, somewhat diagrammatically, in Fig. 1. The two mirrors, (M), (M¹), are mounted at the extremities of iron arms, and are suitably counterbalanced, as shown. The arc is fixed in the center of rotation at (a), and light is incident upon the photometer disk at (c), by the two paths shown in dotted lines, direct light from the arc being cut out by a screen not shown in the figure. This plan necessitates a fixed photometer, P, and, in order that a variable illumination may be produced to balance that due to the arc, I have arranged a cord and windlass, W, permitting the observer to move with facility the secondary standard, S, which is a glow lamp. At D is a long, wooden cylinder, upon which is wrapped the paper to receive the records of the test. These records are made by an electro-magnetic device, R, which punctures the paper whenever an electric circuit is closed at the button, B.

The observer, seated before the photometer in a closely-screened inclosure, operating with one hand the windlass, and with the other the push-button, is enabled to take settings with relatively great rapidity and accuracy. At a point 200 cm. to the right of the photometer disk, a reserve standard is mounted on an arm that may be swung into a position in line with the bar. This reserve standard was carefully evaluated once for all in terms of the Hefner lamp. To determine the intensity of the secondary standard, S, it is only necessary to turn the reserve into position and record a series of readings in the same way as for the arc. This operation is carried out at the end of each test, or more frequently if any change has been made in the temporary standard. Thus, it will be seen that, should the lamp under test be found particularly weak at certain angles, the limit of the bar might be reached in the attempt to get a setting. In such case, it is necessary to stop down the temporary standard and to again refer it to the reserve. I may add that the reserve is never allowed to burn more than a few minutes, and cannot deteriorate under such conditions of use.

With this disposition of the mirrors, the angle of incidence at the photometer disk is constant. In Fig. 1, this angle is shown at more than twice its actual value, in order to reduce the length of the drawing. The real value of this angle is 5° 54′. To make a correction for this lack of normal incidence would mean the division of the intensities, as found, by the cosine of 5° 54′, or .9947. Failure to do this introduces an error of about one-half of 1%, which is clearly neligible in work of this character.

If, at a given instant, I′ be the intensity of the arc to the left, and I″ the intensity to the right, d the fixed distance, abc, d_a the distance of the movable standard and K the mirror coefficient, we have as the mean intensity,

$$I = \frac{I' + I''}{2} = \left[\frac{d^2}{2d_a^2}\right] \times \frac{I_a}{K}$$

The factor in the bracket was computed once for all for values of d_a throughout the range of the bar, and these values were laid off as graduations on a long T-square. To work out the intensities in any particular test, it suffices to pin the record from the drum upon a long table, and to read directly from a T-square the values of the bracketed expression corresponding to the punctures in the paper. The mean of these values for any one position multiplied by the factor to the right of the bracket gives the intensity for that position in Hefner units.

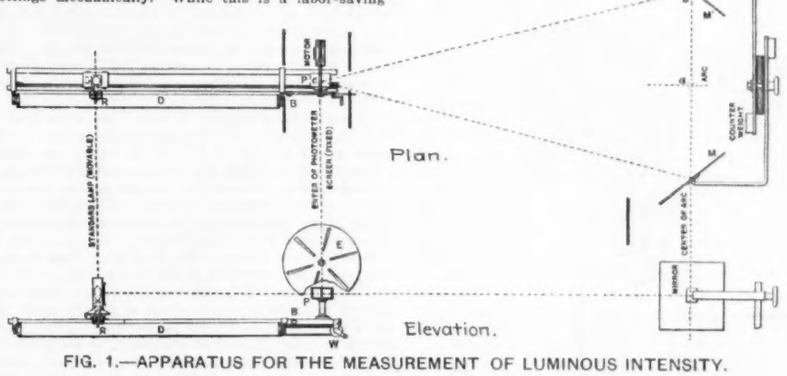


FIG. 1.—APPARATUS FOR THE MEASUREMENT OF LUMINOUS INTENSITY.

It is, of course, necessary in testing sources with large globes or shades to use mirrors of such size that the globe or shade may be seen in its entirety, when the eye is placed at the point C (Fig. 7); and it is further necessary that the distance abc should be large.

It is important to note that the double-mirror method, while enormously diminishing the fluctuation due to wandering of the arc, can have no effect on such fluctuations as are due to variations in length of the arc, or to variations in the current strength.

Of the difficulties peculiar to the method, the most serious arises from the attempt to compare the arc with a standard of different color. It is well known that when the color difference is marked, the setting partakes of the nature of a guess, differing not only with different observers, but with the same observer at different times. To minimize the error due to this cause, I have made use of the physiological fact that, as the illumination of two surfaces tends toward zero, the eye appreciates their difference in color to a less and less degree, and is thus able to estimate an equality in luminosity unhampered by the sensation of color. Thus, the method of winking, or half-closing the eyes, has been used by many experimenters to diminish the color sensation. These latter processes are very fatiguing to the observer, and I have adopted the plan of diminishing the intensity of the photometric field by the use of a rotating sectored disk, showed at E, Fig. 1, of very small angular opening. Ferry has found that the use of a sectored disk to reduce the intensity of one source in comparison with another of different color introduces an error, because the ratio of the light transmitted to light cut off does not appear to be the ratio of the open to the closed sectors when the opening is small. It will be noted that the disk in the figure is so placed as to diminish equally both sides of the photometric field, and hence one would not look for an error of this character.

*Abstract of progress report by Prof. C. P. Matthews, of Purdue University, on a series of investigations being made, and presented by the Committee for Investigating the Photometric Values of Arc Lamps at the annual meeting of the National Electric Light Association, May 22.

†Since writing this, I find that the eminent French photometrist, Blondel, has embodied this principle in his admirable Photomésomètre.

The values of luminous intensity in these tests are expressed in terms of the Hefner amylacetate lamp. They may be reduced to British candles by multiplying by the factor .88. I would call attention, however, to the fact that this is a little more than multiplying by an arbitrary constant, since no one knows definitely what the luminous intensity of the British candle is. On the other hand, the Hefner unit has met with an international sanction, and is quite generally accepted as a unit, far from perfect, but possessing, especially for practical purposes, fewer faults than any unit thus far proposed. I trust that the association may see fit to adopt a complete system of photometric units, as proposed by M. Blondel. There is particular need that a unit of "luminous flux" should receive general acceptance.

When an opalescent inner globe is used, the globe itself becomes more or less luminous by diffusion. The diffusion differs with the height of the arc in the globe, that is to say, with the length of the lower carbon. To ascertain the magnitude of this effect, I have carried through three tests on the same lamp and inner globe, and also the same

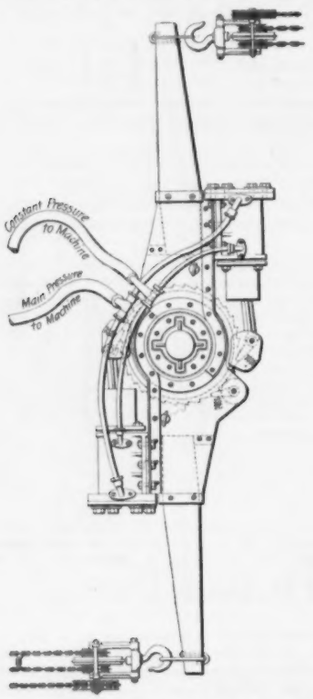


Fig. 1.—General Plan of Hydraulic Screwing Machine for Driving Screw Piles.

carbons, the lower carbons being cut successively to lengths of 4¾, 2¾ and 1¼ ins. An inspection of these results shows that least light is obtained with the arc at the top of the globe, and most light when the arc is at the mid-point. This is explained in part by the fact that with the arc at the top a good part of the luminous flux is incident upon the non-reflecting surface of the gas cap.

In order to determine the status of the direct current, inclosed arc as found commercially on the market, it seemed desirable to study first the questions of luminous intensity, power consumption and efficiency, taking the lamps as supplied by the makers, but operating under a certain uniformity in conditions. These conditions are: (1) The same brand of carbons throughout; (2) an opalescent or milky inner globe, and a clear outer globe; (3) an opalescent inner globe, and an opal ground or milky outer globe. To these, I have added in certain cases a test with no outer globe whatever, in order that the absolute, as well as the relative, absorption of the outer globes might be found.

The lamps are fitted with the proper lengths of carbons, and adjusted, as nearly as possible, to the voltage at the arc named in the makers' specifications. They are then allowed to burn until thoroughly heated before the test begins. One observer maintains the terminal electromotive force constant, and takes readings of the current throughout the test, while another operates the photometer. The values of current given are therefore the mean of many readings. From the records taken off the recording drum the values in the tables are computed. These values are then plotted in polar co-ordinates, as shown in the curves below, and also in rectangular co-ordinates in the well-known Rousseau diagram, which latter is integrated by the planimeter to get the mean spherical intensity. Eight direct-current, 110-volt lamps and seven alternating-current inclosed-arc lamps for constant potential circuits have been tested up to the present writing.

A HYDRAULIC SCREWING MACHINE FOR DRIVING SCREW PILES.*

By Charles William Anderson, Assoc. M. Inst. C.E.

When piles have to be screwed into a hard mass such as rock chalk, a hydraulic screwing machine possesses many advantages over the capstan generally in use. The machine it is proposed to deal with, Fig. 1, had two cylinders with rams 8¾ ins. diameter and 7⅛-in. stroke. The center of the machine consisted of a ring cast to fit the outside of the pile, and was securely bolted to the ratchet-casting. Two arms of elm were fitted to opposite sides of the machine, 11 ft. 9¾ ins. across from end to end, and to the shackles at the ends of these arms were hooked 4-ton differential blocks, the burden-hooks of which were made fast to any convenient portion of the stage in such a manner as to take the "thrust" of the hydraulic pressure in the cylinders.

The admission of water to the cylinders was regulated by a four-way working valve placed upon the upper stage at any convenient distance—generally about 45 ft.—from the screwing machine, and fitted with flexible pipes, 1¼ ins. in diameter, leading to the pumps on one side and to the two cylinders on the other. The forward or working stroke of the pistons was gained by admitting pressure at the back of the cylinders upon the full diameter of those pistons, namely 9⅞ ins. When the full stroke had been taken, by the manipulation of a lever on the working valve the water was exhausted along the same pipe, through the valve and back to the tank of the pumps to be used again, whilst at the same moment a constant pressure in the other end of the cylinder effected the return stroke of the pistons. As this constant pressure was admitted into a space of only 9-16-in. between the body of the ram and the side of the cylinder, it was not sufficient to cause any inconvenience during the forward stroke, but was easily overcome by the greater pressure behind. The effective diameter of the ram during the forward stroke was thus not 9⅞ ins., but 8¾ ins., or the diameter of the body.

The pumps supplying water to the machine had four 4-in. rams with a stroke of 6 ins. They were fitted with an escape valve which could be so regulated as to supply water at say 500 lbs. or 600 lbs. per sq. in., as might be required, 600 lbs. being the pressure most generally in use.

Provided there are facilities for making fast the burden-hooks of the differential blocks, the machine may be placed at any position upon the pile, and screwing may be continued even after it is under water, since the loud click of the pawls sliding over the ratchet-teeth on the return stroke is a sufficient guide for the man manipulating the lever of the working valve. There are, however, objections to working the machine at a very great depth below the pumps, on account of the loss of power incurred during the return stroke of the piston, or the greater difficulty in forcing the water back along the main pressure pipe through the valve to the tank, due to the increased friction encountered in the long length of that pipe, and to the pressure of the additional head of water. In the machine described, some difficulty was experienced in getting a quick return stroke even at a distance of 45 ft. from the pumps. This was rectified in a later machine by enlarging the pipes and thus diminishing the friction, and also by enlarging the valve and increasing the area of that portion of the ram which received the pressure for the return stroke.

The type of pile shown in Fig. 2 was screwed by this capstan into the hard chalk to depths between 10 and 15 ft., and into softer chalk between 15 and 36 ft. The piles were built up of segmental iron ¾-in. thick and were 9 ins. in inside diameter, 10½ ins. in diameter outside the barrel, and 16¼ ins. across the flanges. The lower part

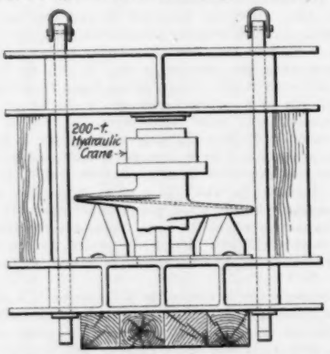


Fig. 3.—Device for Testing the Strength of Screw Blades of Screw Piles.

of the shank was of solid forged iron, 8 ins. in diameter, with the end swelled and turned to fit the inside of the segment iron, and having a collar upon which the latter rested, the connection being made by three steel rivets. The lower end of the shank was "flatted" to fit the socket of a 4-ft. cast-steel screw-blade of 6 ins. pitch of thread. The length of the solid shank was between 10 and 15 ft., and that of the whole pile varied between 30 and 50 ft.

The following are particulars of screwing by the hydraulic capstan under varying conditions: In the first case, when working steadily the piles were screwed at the rate of 4 ft. per hour, or about 6 minutes for every revolution of 4¾ to 5 ins. travel. Operations were much retarded in this case by the difficulty in obtaining a quick return stroke of the piston. In the second case both piles were screwed 5 to 5½ ins. per revolution throughout the whole distance. Although there was greater resistance when screwing in the harder material, no variation in the travel was noticeable. In the third case the average depth screwed per hour was about 4 ft. The material was so hard that it was often found impossible even to enter the blade until weight sometimes to the extent of 20 tons, had first been placed upon the pile. By loading the pile it was always possible to make the blade bite into the chalk, and the travel per revolution could be regulated by weight. A disadvantage of a heavy weight was that the tendency of the pile to twist in its length of segment iron was correspondingly increased, but as it was soon ascertained how far this twisting might be permitted without producing permanent set, no serious results ensued.

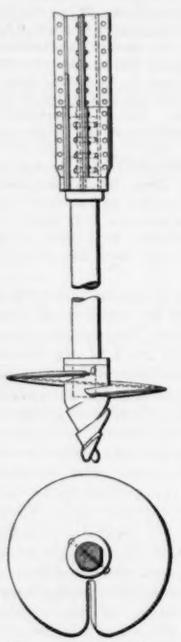


Fig. 2.—Construction of Screw Pile Driven by Hydraulic Screwing Machine.

For screwing into hard material like rock chalk, the blades would be improved by having the cutting-edge more curved away, instead of being square to the axis, so as to present a sliding knife-edge to the obstructions; and the length of the point of the blade should be increased from 1 ft. 7 ins. to 2 ft., in order to center the pile better. When screwing in clay with a blade of 6-in. pitch, the normal results show one revolution of the pile in 3½ to 4 minutes, and a travel of 5 to 5½ ins. per revolution, or taking 4 minutes to a revolution at 5 ins. travel, a depth of 6 ft. 3 ins. is accomplished in one hour. It is expected, with a later machine of the type described, with larger cylinders and other modifications, to obtain 9 ft. per hour when screwing in clay or similar beds.

The advantages of a hydraulic capstan are most apparent when excessive resistance is encountered owing to the nature of the bed, and when the shank friction becomes serious owing to the great depth to which the piles are screwed; but in clay the results do not surpass those obtained by the use of the ordinary capstan worked by an endless rope from hand or steam winches.

Owing to difficulties experienced with cast-iron screw-blades under a heavy load, the following system of testing by hydraulic pressure has been adopted, with satisfactory results, Fig. 3: The blades were supported upon a knife-edge casting placed so as to touch the center of area of the screw, and pressure was applied from above by means of a 500-ton hydraulic press, the whole being encased in a strong frame of cast-iron. The cast-iron blades, 3½ ft. in diameter, with a boss 13 ins. in diameter, and 3 ins. thick at the root and 1 in. thick at the edge, broke at between 52 and 72 tons. Cast-steel blades of the same diameter, but 4 ins. thick at the root and 1¼ ins. thick at the edge, were then substituted, and these showed a bare 1-16-in. deflection with a pressure of 200 tons.

*Abstract of a paper presented to the Institution of Civil Engineers.

150-TON CANTILEVER CRANE TO BE BUILT AT KIEL GERMANY.

In our issue of Feb. 8, 1900, we described a very large crane of novel design which had been erected at the Imperial Docks at Bremerhaven, Germany. A crane of equal size, but somewhat different design, is described in a recent issue of the "Zeitschrift des Vereines Deutscher Ingenieure," and we translate its description as follows:

This crane was designed and is now being built by the Duisberger Machine Works, formerly Bechem & Keetman, of Duisburg, Germany, for the Krupp Germania Wharf at Kiel. The order for this exceptional structure was given in the

fall of 1898 and it was expected that it would be in operation by April, 1900; but various circumstances deferred the date of expected completion to the fall of 1901, and then to April, 1902.

The accompanying plan and elevation show the general design of the structure. It will be seen that the main supporting tower is in the form of an equilateral triangular pyramid. At the apex the three main posts are connected to a ring, the inner side of which carries a track for rollers on the mast. The mast, which stands in the center of the pyramid, rests on a turntable at its foot, which is held from lateral displacement by a center pin. The mechanism for rotating the mast and cantilever is placed at the upper turntable instead of the lower. The cantilever arm has an extreme length from the center of 124 ft. 8 ins. and carries two independent trolleys. The smaller and outer one will carry a load of 45 tons at a radius of 115 ft. 8 ins. and the larger one is intended for a load of 150 tons at a distance of 74 ft. 7 ins. The test load of the latter is placed at 200 tons. Besides these there is a third small hoisting apparatus for loads of not more than one ton placed in the operator's cage near the mast. This is to be used in repair work, etc. The total height of the crane to the upper side of the arm is 118 ft., and to the top of the large trolley, 131 ft. 3 ins. By the elevation of the latter an additional height to which the hook may be raised is secured, amounting to 11½ ft. The motive power is electric. The operator's cage contains the regulating devices controlling the movements of the whole structure. The adoption of independent legs for the supporting tower leaves room for three standard gage railway tracks to pass between these legs with plenty of head room above them. The first tracks passes between the two legs standing on the edge of the wharf and the mast, at a distance of 19 ft. from the edge of the wharf. The two other tracks lie between the mast and the third post at distances of 46 ft. 9 ins. and 59 ft. 9 ins. from the edge. The great advantages of this arrangement are apparent on comparison with other cranes. For example, with the great crane at Newport News (Eng. News, Feb. 23, 1899), the nearest that a track can be placed to the edge of the wharf is 59 ft. 6 ins, and with the Bremerhaven crane, 57 ft. 5 ins.

THE TAYLOR-WHITE TOOL-STEEL PROCESS OF THE BETHLEHEM STEEL CO.

The Bethlehem Steel Co. recently extended an invitation to the various technical papers to send representatives to its shops at Bethlehem, Pa., on July 31 for the purpose of inspecting the results obtained in actual work with a new kind of tool steel. Some half a dozen journals, including Engineering News, responded by sending representatives, who were most cordially received and entertained by the officers of the company.

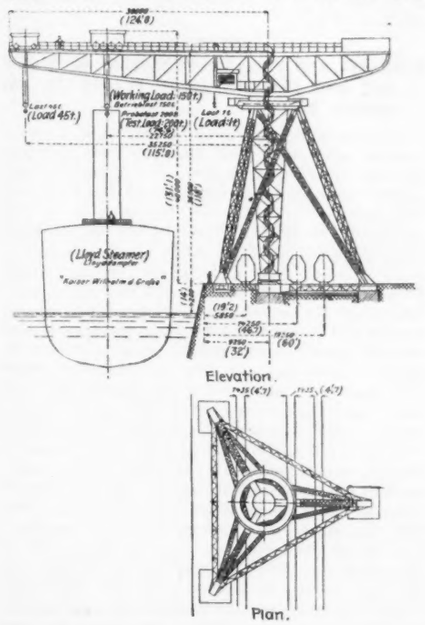
The process above mentioned is the joint invention of Mr. F. W. Taylor, Consulting Engineer, and Mr. Maunsel White, Engineer of Tests of the company. Some years ago Mr. Taylor was retained to reorganize the shop methods in vogue at Bethlehem, with a view to greatly increasing the output with the existing equipment. It was found that the forge shop had outrun the machine shop to such an extent that it appeared that the latter, costing a million dollars or so, would have to be duplicated.

Mr. Taylor first sought to systematize the management of the shop and to increase the output per unit, with the aim of ultimately placing all work on the piecework system. It was found that one of the first requisites was a perfectly uniform and dependable quality of tool steel, as with it only could be determined the maximum possible performance of a man or a machine. Investigations were accordingly taken up with the view of producing such a grade of steel. These researches have culminated in the perfection of a process of tempering and hardening tools that give results greatly superior to any heretofore attained both in uniformity and efficiency, as is demonstrated in the shops of the company.

The new steel may be used at cutting speeds two to four times greater than those possible with other steels. The main lines of shafting of the shops have been speeded up from 90 to 250 revolutions per minute, and the gain in the average amount of metal cut per hour throughout the shop is shown in the following table:

Average.	Oct. 25, 1898.	May 11, 1899.	Jan. 15, 1900.	Gain in cut of 3d over— 2d., %	1st., %
Cutting speed, per min...	8' 11"	21' 9"	25' 3"	16	183
Depth of cut	0.23"	0.278"	0.30"	8	30
Feed	0.07"	0.0357"	0.087"	32	24
Metal removed pr hr., lbs	31.18	81.52	137.3	68	340

On the day of the visit above mentioned several tests were made to show to the visitors the superiority of the new steel over other brands, Mushet steel being taken as a representative of the latter. A heavy cut was taken on a very hard piece of cast-iron for 15 minutes with a special process tool, which showed no signs of wear, being only slightly discolored at the point. A tool of Mushet steel on being substituted lasted only 22 seconds, the speed, feed and depth of cut remaining the same. A piece of steel shafting was placed in the lathe and run at a cutting speed of 150 ft. per min. The tool became red at the tip but maintained a very good cut. On being removed it still showed a good edge, being only a little hollowed out by the escaping chip on the upper side. It was replaced by a Mushet tool,



The 150-Ton Electric Crane at the Krupp Germania Wharf, Kiel, Germany, Designed by the Duisburg Machine Works, Duisburg, Germany.

which lasted only two revolutions, at the end of which the nose was completely worn away.

Ordinary tool steel will not stand a temperature above 600° or 700° F., while the new steel may be worked to a temperature between 1,100° and 1,200° F. When working without water and at the maximum rate upon steel the chips oxidize to a deep blue immediately upon leaving the tool. This enables the foreman to know at a glance whether or not a machine is being worked to its full capacity. These blue chips were to be seen throughout the shop, where the new steel is used exclusively on all varieties of work.

As to physical properties, the improved steel is said to be slightly higher in tensile strength and elastic limit, and to be somewhat softer than ordinary steels. The latter property excludes it from use in making finishing cuts.

Although patents are pending, the method of manufacture is a secret, which the officers of the company declined to reveal. The new process is said to greatly improve the steels now in use, but its effect is most marked on a special steel, the composition of which is also withheld. The improved process undoubtedly consists in exact methods and improved appliances for heating, hardening and tempering.

BOOK REVIEWS.

THE BACTERIAL TREATMENT OF SEWAGE.—A Handbook for Councillors, Engineers and Surveyors. By George Thudichum, F.C.S. London: The Councillor & Guardian. Paper; 5 × 7 ins.; pp. 92. 1¼ shillings in Great Britain; 50 cts. in the United States.

The author believes that of all the various methods of sewage treatment recently tried in England, two are far superior to all others, and at the same time include practically all there is if value in the other processes. These two are the so-called Sutton or Dibdin bacteria beds, and the septic tank; involving, respectively, aerobic and anaerobic bacterial action. From such a point of view, the author presents the subject of sewage treatment in a clear and interesting manner, making a remarkably handy and valuable booklet.

THE ENGINEERING WORKS OF THE KISTNA DELTA.—A Descriptive and Historical Account. Compiled for the Madras Government by Geo. T. Walch, M. Inst. C. E., Chief Engineer for Irrigation, Madras (Retired). Cloth; 7 × 10 ins.; Vol I.: pp. 191; illustrations and tables. Vol. II.: 37 plates. Madras; Superintendent of the Government Press. 15½ shillings in Great Britain and the Colonies; $6.20 in the United States.

This monograph describes the vast irrigation system developed in the Kistna (or Krishna) delta. A dam, or anicut, has a total length of 3,714 ft. and the highest flood discharge over it was estimated as 770,000 cu. ft. per sec. There are 336 miles of main canals and branches, 295 miles of which are navigable; besides the subsidiary canals and ditches. About 519,000 acres of land were irrigated during the year 1897-98, against 18,967 in 1855-56, the year the great dam was finished.

THE INFLUENCE OF STRUCTURE ON THE WEARING POWER OF PAVING BRICK.—By Edward Orton, Jr., and Albert Victor Bleininger. First Annual Report of the Committee on Technical Investigation, National Brick Manufacturers' Association. Indianapolis: T. A. Randall & Co. Paper; 6 × 9 ins.; pp. 107; illustrations and tables. $1.

The good work done by its committee on tests of paving brick, 1895-97, led to the establishing by the association of a permanent committee to carry on needed investigations in the field of brick-making. Combined with the work is a fellowship in the University of Ohio, supported by the association. Mr. Bleininger, the junior author of this monograph, won the scholarship in a spirited competition. Various phases of brick-making, related to structure, are reviewed in this report, including side-cut against end cut, effect of repressing, size and shape of paving brick. The conclusions are given elsewhere in this issue.

GAS AND ELECTRIC LIGHTING WORKS DIRECTORY AND STATISTICS, 1899. With a List of Chairmen, Managers, Engineers and Secretaries and Lists of Associations of Engineers and Managers of Gas and Electric Lighting Works in all Parts of the World. London: Hazell, Watson & Viney. Cloth; pp. lxix + 393. Six shillings in Great Britain; $2.40 in America.

It is interesting to note that the section of this book devoted to descriptions and officials of gas-works occupies about 315 pages, against only some 30 pages for electric lighting plants. This, we presume, indicates approximately the relative number of each class of undertakings in England, Wales, Scotland and Ireland. Under gas-works, the principal items are: Location and population of town or district supplied, owner, date of construction, loans outstanding and paid, rate of interest, coal and oil consumption, output and sales of gas, candle-power required and furnished, number of consumers and of public lamps, together with private and public charges, length of mains, officials and outside towns supplied. The same general plan is followed for electric lights.

FURNITURE DESIGNING AND DRAFTING.—Notes on the Elementary Forms, Methods of Construction and Dimensions of Common Articles of Furniture. By Alvan Crocker Nye, Ph.B., Instructor in Furniture Designing, Pratt Institute, Brooklyn, N. Y. New York: Wm. T. Comstock, Publisher. Cloth; 10¼ × 6⅞ ins.; pp. 100; illustrated. $2.00.

In this book of reference for the architect and student interested in furniture designing, the author treats of dimensions, the relations of parts to each other, the limitations due to construction and of fitting decoration. He follows Ruskin in pointing out that furniture should not only be well put together and strong; but it should also appear to be strong to the eye. He takes as his illustrations the commoner articles of furniture; but he gives the purpose of each of them and shows how they should be proportioned and designed so as best to meet the conditions imposed. Upholstery, paneling, moldings, joints, and general construction are fully and well treated. Ornamentation has a chapter by itself; and here the author points out the difference between good and bad ornamentation, and the principles upon which ornament should be applied. It is an excellent work for the purpose intended.

THE SHAWENEGAN FALLS WATER POWER electric plant of the Shawenegan Water Power Co., of Canada, it is stated, will be ready to supply power to Montreal, Canada, over a transmission line 80 miles long in the spring of 1901. At first the works will develop 30,000 HP., but it is stated that the plant will subsequently be increased to develop 75,000 HP.

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We are glad to report another addition to the list of States having bacteriological laboratories at their command for the examination of water. Through co-operation with the State Board of Agriculture, the State Board of Health of North Carolina announces that it has made provisions to the end named. This suggests that other boards, State and municipal, might more often co-operate to maintain laboratories, until the time arrives when each board can have, or needs, an independent laboratory. The urgency for more strict watchfulness over water supplies in North Carolina is evident from the same bulletin of the board as contains the announcement already noted, for it appears that not long ago "one-third of the total college pouulation" of the State Normal and Industrial College at Greensboro, N. C., had typhoid fever, which was believed to be due to polluted water from a well on the premises. There were 14 deaths.

The scholarship in municipal government, recently founded at the University of Wisconsin by the League of Wisconsin Municipalities, is a practical line of work that might be carried on with advantage by other organizations devoted to the improvement of city affairs. The scholarship is maintained from the membership fees of the league, and the recipient aids in editing "The Municipality," published by the league. Prof. Samuel E. Sparling, of Madison, Wis., is editor of "The Municipality," and Dr. Geo. Ray Wicker, who was recently elected instructor in economics at Dartmouth, held the scholarship last year.

A somewhat similar, but more ambitious, undertaking in the interest of municipal administration is reported from England. Under the Chadwick Trust, which is in charge of the Society of Arts, Chairs of Hygiene and Municipal Engineering have been provided for at the University College, Gower St., London. About $5,000 is available for the equipment of a laboratory of bacteriology and hygiene, cement, brick and stone testing apparatus and surveying instruments. Some $500 a year is to be available for the renewal of laboratory apparatus, and some $3,500 a year is provided for salaries of professors and instructors. There is also a Chadwick scholarship of some $500 a year, a medal, and various other provisions for work under the Chadwick Trust. A full account of the conditions of this trust and a report of the work under it during the last year is given in the "Journal of the Society of Arts" for July 13, 1900.

The concluding paragraph of the last report of the Chadwick Trustee, Mr. R. B. Carter, throws such an interesting sidelight on the eminent sanitarian who founded the trust that we quote it, as follows:

> The trustees being authorized, if they deem it necessary, to present a shield or medal, to be called the Chadwick Shield, to any local sanitary authority which, having adopted the separate system of drainage advocated by the testator, was able to show a materal reduction of the death rate of its district after five years' trial, as demonstrated by its official statistics of death rates, duly advertised for local authorities who laid claim to the award. Very few applications were sent in, but the trustees came to the conclusion that none of the drainage works (on behalf of which applications had been submitted) came within the definition of the separate system of drainage as set out in the scheme, and the award was therefore not made.

MUNICIPAL AND PRIVATE OWNERSHIP OF WATER, GAS AND ELECTRIC LIGHT PLANTS IN THE UNITED STATES.

A monumental collection of statistics, designed to show the results obtained under municipal and private ownership of water, gas and electric light plants, has just been published by the U. S. Department of Labor, under the direction of Col. Carroll D. Wright, the head of the department. The report, which occupies 983 octavo pages, presents detailed facts and figures relating to the physical characteristics, and also one year's operations, of 375 private and 659 municipal waterworks; 356 private and 11 municipal gas works; and 632 private and 320 municipal electric light plants. This makes a total of 2,353 works, or a little less than one-third of the total number of water and lighting plants in the United States, which is placed at 7,323. A much larger proportion of total investment and of total value of product was covered by the investigation, since some of the largest plants are several hundreds of times as big as the smallest ones. Thus, while the 659 municipal water-works included constitute 37% of all the municipal water plants, it is estimated that they represent 90% of the cost and 93% of the output value of all the municipal water-works. This is an extreme illustration, the corresponding figures of value for private gas and electric light plants being about 45%. Obviously, the investigation was broad enough, as to number and importance of plants, to be representative of each kind of works and class of ownership, although the small number of municipal gas plants (11 are included, out of 14 for the whole country) makes it necessary to be very careful in comparing public and private ownership in this division.

The relative advantages of municipal and private ownership is now occupying so much of the time of all persons interested in municipal affairs, and the movement for municipal ownership is attaining such volume and strength, that the adherents of each side of the question, as well as those who are merely seeking for the truth, are eager for conclusive facts and figures. What does this vast mass of statistics show? Unfortunately, as it seems to us, this question is not answered definitely, if at all, in the report itself, which is little more than a vast storehouse of facts and figures from which conclusions may be drawn only after thoroughly mastering the methods pursued and making new summaries, or at least revising the few summaries that are presented. We are aware that this may sound ungracious, in view of the great amount of valuable information here given, which far exceeds anything heretofore accomplished in this country, both in magnitude and apparent thoroughness; nevertheless, the report itself is the best of evidence that but little attempt has been made in it to draw definite conclusions and that those are nowhere put in concise and lucid form; while in addition we believe that some of the methods employed, or neglected, go far towards nullifying the few conclusions that are presented. We have to confess that these opinions are based largely on an examination of the statistics and explanatory matter relating to water-works, which study required so much time as to leave but little available, for the present, to devote to gas and electric lighting. But as the same general plan was followed in the three grand divisions of the report, it seems likely that our conclusions relating to water-works are equally applicable, with minor variations, to the other classes of public utilities.

The statistics presented in each of the three divisions are grouped in eleven tables. Table I. in each division, may be said to be a physical description of each plant, including the year of original construction and the date at which the present ownership began. Table II. relates wholly to fuel conditions, with the water supply added in the case of the lighting plants. Table III. is an analysis of the cost of the several works. Table IV. shows, for public works only, how the money to pay for the plant was raised. Table V. is an analysis of gross income, Table VI. of cost of production, Table VII. of output; each for both private and municipal works. Table VIII., for municipal works, only, is an attempt to distribute the cost of production between private consumers and the public service, while Table IX. gives "certain additional elements theoretically entering into cost in municipal plants." Table X. shows profit and loss, for private plants, and Table XI. purports to give the average price per unit to private consumers and also for the municipal service, for both classes of ownership. In each of the three grand divisions the works are arranged in the order of magnitude of total yearly output, except that for electric light plants the gradation is by total horse-power of engines. Water-works are thus subdivided into 20 groups, gas plants into 11 and electric light plants into 16. There are no averages of any sort, at least under water-works, comparing all the private with all the municipal plants, but there are three such sets of averages, by output-groups, namely: Wages and salaries (each separately); cost of production; and average price per unit (1,000 gallons of water). This last set of averages appears to have a fatal inconsistency, mentioned further on. It is founded on Table XI., which, the introduction states, is believed to "furnish the proper basis for the comparison of plants operating under private and under municipal ownership." The first two sets of averages are founded on Table VI., cost of production. No comparisons of plant against plant, under the two kinds of ownership, are given, so the only attempts at comparison between the results of private and municipal ownership are based on Tables VI. and XI. The other tables either lead up to these, or furnish a basis for determining how far any one plant is physically comparable with another, or help explain some of the apparent inconsistencies in the figures for a given plant.

Let us now examine in more detail the scope of the inquiry and the methods employed in presenting results, confining ourselves, unless otherwise stated, to the section on water-works.

First of all, it is to be noted that the subdivision of each class of works into groups based on the total amount of water supplied for the year, while perhaps the best classification possible, in view of all the circumstances, has some serious drawbacks. The chief of these are: (1) That for nearly all the gravity works, and a large percentage of the pumping plants, the total yearly consumption ranges all the way from a wild guess to an approximate estimate; and (2) the enormous waste of water in connection with many works throws them far out of their proper class, as compared with most any other basis of classification.

It was considered impossible to give populations, since they would be an easy means of identifying the location of the several plants, which it was considered absolutely necessary to prevent, if figures from private companies were to be secured. This limitation seriously detracts from the value of the whole study, since it is one of the

chief means of judging whether the conditions surrounding any two plants, or groups of plants, are comparable. We do not say that population would be a better basis of classification than total yearly consumption, but it is quite essential to a proper understanding of the vagaries of the latter. We are aware of the difficulty of securing accurate population figures for intercensus years, but probably estimates of population would be quite as reliable, in most cases, as the estimates of consumption given in the report. It should be noted, too, that the report contains no warning, so far as we have seen, that many of the figures for total output are estimated.

In the absence of population figures, the returns contain little or nothing to indicate how amply the various communities are supplied with water, nor how lavish is their use, nor how criminal their abuse, through waste, of the water furnished them. With one other exception, noted below, the physical data is surprisingly complete, but these two exceptions, or omissions leave one hopelessly in the dark at several points when attempting to determine the individual or relative standing of the various plants. The second exception, or omission, is the number of taps or service connections between street mains and houses. Had these been given, even without populations, they would have afforded a most valuable check on some of the figures presented, while both taps and populations together would have increased the value of this section of the report many fold. With the number of taps given, a comparison of the use and waste of water, by works, and groups of works, might have been instituted, thus throwing much light on the variations in cost of product, charges for service and income. The importance of some check of this sort is evident when it is remembered that the financial comparisons are based on consumption units. Thus, if one wishes to compare wages or salaries, a very low salary cost per unit of water supplied may be due to an enormous waste of water, or vice versa. Or again, the figures purporting to show the prices per unit paid by private consumers may appear to be remarkably low when they are actually very high, since they are the result of dividing the total revenue from private consumers by the total consumption and waste less the estimated consumption for public purposes. Where half the amount of water pumped is wasted, for instance, as is often the case, the actual unit cost of water to private consumers would be double the rate shown in the tables; and there is no means of checking it, either, as there is for some of the absurd figures which are presented as the cost per unit of water supplied to the municipality.

Having pointed out the chief omissions of physical data, it is only fair to emphasize the fact that otherwise the statistical descriptions of waterworks are very full. The classification of the different parts of the works is in some respects odd and in others ambiguous. We cannot refrain from quoting the first part of a definition of a standpipe, which, with some other features of the report, suggests that the U. S. Department of Labor might consult an engineer to advantage, in case it enters on another investigation of this sort:

> A stand-pipe is a large pipe, or structure in the form of a pipe, erected on an elevated spot. Generally it stands on a foundation of masonry, and is enclosed in a stone or brick construction for a part of its height, above which it is enclosed in an iron or steel casing (such casing may rest on the foundation), above which there may be a trestle or tower, or the casing itself may extend to the top. This casing is for protection and support.

Attention has already been called to the estimates of consumption. There are, of necessity, many other estimates, some of which must be guesses, like many of the attempts to distribute the cost of the works in accordance with the classification of the physical data of the plants, for works where detailed records were lacking. The estimates for depreciation, the report states,

> represent in each case the closest obtainable estimate of the loss in value during the year of each of the plants exclusive of land over and above the expenditures for repairs and renewals, the estimates being based on the best judgment of the official of the plant who furnished the answers to the inquiries submitted by the Department.

The wide variations in rates of depreciation, as shown by the returns, is accounted for by differences in age of plants, "a large or small expenditure for repairs and renewals." In some cases of small or no allowance for depreciation

> the agent of the Department was informed that a thorough overhauling of the plant had been made the previous year, a large sum having been expended on the same, and that, as a consequence, but a small amount, if, indeed, anything at all, was properly chargeable to depreciation during the year of the report.

It may be worth while to see how these figures for depreciation run in a group where all the plants are both old and large, thus eliminating newness of plant and the vagaries of small works. The twelve water-works of largest gross annual output, all supply 10,000,000,000 gallons or more a year, were built at various dates ranging from 1800 to 1879. Plant No. 1,029 is rated at 0.06% depreciation on the total investment of $28,938,402, or $15,365, not including land. It is put down as constructed in 1824, and as having its present ownership date from 1848. Plant 1,024 is debited with a depreciation of 10% on a total cost of $10,427,890, or $1,015,034, not including depreciation on land. This plant was built in 1821, and its present ownership dates from 1836. Plant No. 1,029 takes its whole supply, primarily, by gravity through long masonry conduits, while No. 1,024 pumps all the water from an apparently nearby source, but No. 1,029 has 73,500,000 gallons of daily pumping capacity, to supplement the gravity supply, against 122,688,200 gallons pumping capacity for No. 1,024. It would not be difficult to locate these two plants, but since it is supposed to be impossible we will not attempt it. Plant No. 1,029 has 29% of its total investment in storage reservoirs at the source of supply, 15% in conduits, or aqueducts, 2⅓% in pumping equipment, and 1⅓% in distributing reservoirs. Plant No 1,024 has no storage at the source of supply, no aqueducts, 27⅓% of its investment in pumping plant and 22% in distributing reservoirs. Each plant has about 45% of its investment in mains. The comparison might be extended further, but enough figures have been given, we believe, to render it doubtful whether the 0.06% in one case and the 10% in the other can both be right. The two plants were selected for comparison, we may add, because they were the extremes for this group, and before the other comparative figures were taken from the several tables. The other figures for depreciation in this group are 0.5, 3.0, 3.0, 2.0, 0.2, 5.0, 3.0, 0.48, not given, and 2.0% of the toal investment, or cost of works.

The theory on which the estimates of depreciation were based seems to have been that these figures should equalize the variations in thoroughness of repairs, so as to put the several plants on the same plane of expense for general repairs and maintenance, but if this had been carried out to the bitter end would not depreciation have gone far above 10% in many instances? In other words, if newness of plant, or a recent thorough overhauling warranted a minor or no allowance for depreciation, might not the conditions be such, in some cases, as to require, in fairness, a depreciation of much more than 10%? In only one instance is that rate exceeded, a single private plant being charged with 15%. Might it not have been better to assume a uniform rate of depreciation of the various elements of the works, the cost of which is reported separately, instead of allowing such unbounded opportunity for the personal factor to enter in, as is bound to result when each superintendent or other official judges his plant and his own administration thereof in accordance with his own individual notions? It must be remembered that only a small proportion of water officials are engineers, particularly in the smaller works, and that even among the best engineers depreciation of public works is a mooted question. To anticipate any objections to including depreciation in the cost of production, the Department has presented these figures of cost, both with and without depreciation, and it has done the same for taxes.

There are several criticisms that might be made of Table VI., on cost of production, but lack of space compels us to pass it by, particularly as we have already alluded to it in discussing the relation of waste of water to unit costs. Mention must be made of Table IX., "Certain Additional Elements Theoretically Entering into the Cost in Municipal Plants." These elements are value of rental quarters occupied rent free, estimated taxes and interest on total investment. As the figures in this table stand entirely by themselves, they need not be noticed except for the fact that their sum total is here debited entirely against the unit-price of "water used by city," the results ranging all the way from a fraction of a cent to $96.44 per 1,000 gallons. Why all this cost should be thrown onto the municipal service it is hard to say. The folly of stating it in terms of water consumed, instead of hydrant rental, if it is to be put on that service, is discussed further on.

As has been stated, Table XI. is considered by the Department as the principal one for purposes of comparison. It presents for both private and municipal plants the average price per 1,000 gallons to private users for the metered and unmetered service, and also for both services. In addition, there is a table headed "average price (when bought) or cost (when produced) per 1,000 gallons to city." This means the cost of water used for municipal purposes, under private and public ownership, respectively. We have already commented on the fact that these figures are very misleading where there is much waste, and are based largely on estimates of consumption, except for the metered service. That is to say, in many works the total consumption is estimated, and if there are no meters all the figures are based on estimates. The municipal consumption is almost invariably estimated, so where there are no meters it will often happen that the prices for both private and public service are based on estimates of consumption, the former being the result of subtracting estimated public from estimated total consumption; while where there are meters the same method is followed, after deducting the metered consumption.

Taking the figures for the cost of private consumption for what they are worth, we pass to the cost of water supplied to the municipality. For private works, the total cost of this service is whatever sum the franchise or contract provides, but for municipal works it is the difference between the total receipts and the cost of production, ranging from nothing, or a handsome profit, to $145 per 1,000 gallons. This method of determining the gross cost of the municipal service, for municipally-owned works, is unscientific, while the unit-price chosen is absurd for either private or municipal plants. The gross figures on which the unit-price of water used by the city under municipal ownership are based, have some value, as showing to what extent the private consumers are paying for both the private and public service, but the unit-prices are worse than meaningless. Thus, let us take plant No. 1,034, which used and wasted 96,918,782,023 gallons of water in 1897. Now almost half of this amount is set down as used by the municipality, or 42,040,397,023 gallons (notice the figures in the tens and unit place). Now it happens that Table XI. shows that the cost of all this water to the municipality was nothing, because "income from private users exceeds cost of production." But supposing there had been a (plus) difference between income and cost of production, it matters not, for purposes of illustration, how big or how little; and suppose that instead of guessing that half the total amount of water furnished was used by the city the guess had been 5%, which is reasonable, as guesses go, then the unit-price in the two cases would be as 1 to 10. All through Table VII., giving "Quantity of Product," the proportion of water used by the municipality to the total consumption bobs up and down in a very mysterious way; or at least the high upward range of the figures is mysterious. This table is the source of the quantities used in computing the last column of Table XI., under consideration.

Now as to the unit-price of the municipal service: Taking private ownership first, which is the only class for which we have any proper figures for gross cost of municipal service, we find that for plant No. 66 the cost of the municipal service is reported as $140 per 1,000 gallons. The total quantity used by the municipality, as shown by Table VII., was 10,000 gallons out of a total of

7,510,000 gallons. This is equal to about 20,000 gallons a day. There were no meters in use. The gross income of this plant for the year was $4,195, including $1,400, or about one-third the total, from the municipality. The average cost of water sold to private consumers is given in Table XI. as $0.3727 per 1,000 gallons, against the $140 for public service, already cited. Now, if instead of using dollars per 1,000 gallons as the unit-price of the municipal service, we employ dollars per hydrant, we have $1,400 ÷ 58 (hydrants) = $24 per hydrant, which is a very moderate unit-price, indeed, for the public service, and it is the one commonly employed.

The foregoing was a private plant. Applying the same method to plant No. 30, owned by the city, we get something like a reasonable unit-cost, even though the gross cost of the municipal service is reached by the unscientific plan already described. This plant is set down as supplying water to private consumers at $0.1011 per 1,000 gallons, and to the city at $145. It furnished only 3,510,000 gallons for the whole year, of which 10,000 gallons was assigned to the municipal service. On the basis of hydrant rental (omitting the detailed figures) the water cost the city only $63 per hydrant. This, however, does not include the "Certain Additional Elements" of Table IX., or in this case, an estimate of $120 for taxes and $535 for interest, or $655 in all, which on the basis employed in Table IX., adds $65.50 per 1,000 gallons to the cost of the municipal service, making it $230.50. On the proper basis, assuming that all the charges of Table IX. should go against the municipal service, we have $28 per hydrant to add to the $63 already found, making $91 in all. Certainly $91 per hydrant, in a place using an average of only 10,000 gallons of water a day for all purposes, seems more reasonable than $230.50 per 1,000 gallons as the cost of the municipal service.

In the summary comparing the average price per 1,000 gallons of all water sold, under each class of ownership, the price for municipal plants is based on private consumption only, which of course raises the unit-price, particularly where high estimates for municipal consumption are used.

There remains space for only one or two more brief criticisms before our concluding remarks. While the sources of the total investments in, or costs of, municipal works are given, they are not presented for the private plants. The reason for this is said to be the desire to avoid all the confusion of the capitalization of private companies, and to base comparisons on actual investments. It may be desirable that the comparisons should be so based, but an investigation of public and private ownership without the capitalization of private companies, their rates of interest on bonds and their dividends, is hardly what would be expected. Moreover, in giving the cost of production, including interest and depreciation, the interest on the private plants is assumed as the rate paid on the last issue of city bonds, which suggests ideas which we should like to present, but cannot in this issue.

Finally, so far as comparisons are made between the different kinds of ownership, they are generally favorable to municipal ownership. Now, our criticisms are designed primarily to show that these conclusions must be taken, and any comparisons based on this report must be made, with extreme caution. We are thankful for the investigation and its results. The original statistics forming the basis of the report seem to be very valuable, and promise to be useful for other studies besides those of municipal ownership. Considering the difficulties involved, high praise should be given the Department of Labor for this great piece of work.

LETTERS TO THE EDITOR.

Still Another Formula for Estimating Brickwork in Sewers.

Sir: The following formula for cubic content of sewers is applicable to any size and any shape so long as the wall of the sewer is of uniform thickness. Let p be the inner perimeter in inches; t be the thickness of wall in inches. Then cubic feet per running foot $= \frac{1}{144}(pt + \pi t^2)$. If we consider 18 brick per cubic foot this becomes number of brick per lineal foot $= \frac{1}{8}(pt + \pi t^2)$. For instance: p in a circular sewer is equal to $\frac{d}{4}$, d being diameter; therefore .393 t (d + t) is number of brick per running foot. The perimeter of an egg-shaped sewer is 3.965 d, when d is the horizontal diameter; whence, number of brick = t (.496 d + .393 t). Or (see Eng. News, July 12): d = 24 ins.; t = 9 ins.; for egg-shaped sewer. Cubic feet per running foot $= \frac{1}{144}(3.962 \times 24 \times 9 + 3.1416 \times 81) = 7.71$ cu. ft., requiring 139 brick at 18 per cu. ft.

Yours truly, Chas. H. Tuttore.

Foot of Main St., Buffalo, N. Y., July 13, 1900.

Stresses in Circular Plates.

Sir: I would like to reply to the communication of Mr. d'Auria in your issue of July 5, relating to his method of finding the strength of flat circular plates. He waives aside my objection to the method in regard to only tensile stresses being taken into account by quoting from Professor Goodwin the simple statement that the problem of bending is more complex if horizontal motion of the supports of a fixed beam is prevented.

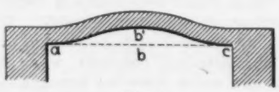


Fig. 1.

The plate will evidently assume the shape shown in Fig. 1. Of course, when I say that there are compressive stresses on the inside of the plate, I do not mean that all of the inner layer is in compression, but only the part toward the center of the plate, which is the critical point. Around the edges, obviously, there is tension. The mere fact that the length of the curved line a b' c is greater than a b c is no proof that the line is all in tension. Part of it could be stretched out, while the remainder is shortened, and the resultant be greater than the original length. The curvature of the plate is proof that the inner fibers are in compression, or, at any rate, are not under the same tension as the outer, since the original shape of the plate was flat. Mr. d'Auria's method assumes that all of the fibers at the center, throughout the depth of the plate, are in tension to the same degree; and, in fact, the only difference in this tension in the entire plate is due to the inclination of the surface of the spherical shells into which he divides the plate. So that, practically, his plate would be in the same degree of tension throughout.

If the plate assumed the shape of a segment of a spherical shell, as shown in Fig. 2, such a condition might exist, but the resistance to horizontal shear between the lamina composing the plate would prevent this.

Fig. 2.

The fact that a formula agrees in result with another formula, assuming the second to be correct, in no way proves the correctness of the method of the deduction of the first. Compensating errors can easily be made. There is no analogy in Mr. d'Auria's method to anything else with which we are familiar. The case under consideration is evidently one of flexure, although the conditions are different from those usually considered.

Very respectfully, Edward Godfrey.

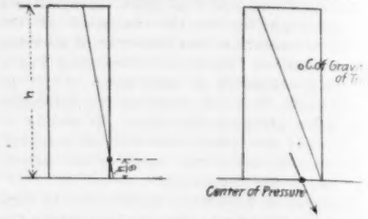
400 Monongahela Bank Building,
Pittsburg, Pa., July 7, 1900.

Conversion Formulas for Retaining Wall.

Sir: Vauban's rule is much more simple than that of your correspondent, on page 410, June 21, 1900. Revolve the front face about a horizontal axis situated in the face of the vertical wall, at one-ninth the height of the wall. This solution is correct within 1-120 if the new batter does not exceed 1-6, or within 1-70 if the batter is 1-5th. Also Rankine: The figure of a vertical retaining wall may be modified without diminishing its stability, so long as the center of gravity of the part taken away does not fall behind a vertical through the limiting position of the center of pressure of the base. H.

New York, N. Y., June 21, 1900.

Sir: Referring to Mr. F. M. Thomas's letter, printed in your issue of June 21, I would like to submit a graphic solution of the problem, which seems to me to be very simple and convenient. Before giving my geometrical construction, I beg to be allowed to inform Mr. Thomas that—so far as I can gather the expressions "rule of thumb" and "graphic solution" are not synonymous, as he seems to imply in his allusion to Mr. Trautwine's method (a method, by the way, which, although jealously marked "original," will never bring much glory to its author as a geometer). As to the relative advantages of the graphic and the analytic method, I myself think that the latter



is by far preferable in the majority of cases, being more certain and direct, and better adapted to the general solution of problems. Notwithstanding this, graphic methods are often simpler and more expeditious, specially for the draftsman.

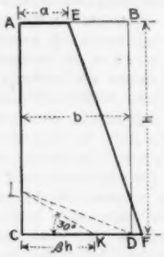
In the accompanying diagram, A B D C is a retaining wall with vertical sides, which it is proposed to "transform into," or replace by, a trapezoidal wall A C F E, of the same material, having the same stability, and whose back E F shall have a given inclination or batter β (= cot E F C). The problem is to determine the point F.

With the notation shown in the figure, Mr. Thomas has succeeded in showing that the distance $\overline{CF}$ is given by the equation

$$\overline{CF} = \sqrt{\frac{\beta^2 h^2}{3} + b^2} \qquad (1)$$

This formula leads to the following construction:

Lay off $\overline{CK} = \beta h$; draw KL at 30° with CD, intersecting A C at L; take the distance $\overline{LD}$ in the dividers and lay it off from C to F; lay off $\overline{AE} = \overline{KF}$. Then will C F E A be the required wall. The correctness of this



construction is very easily shown. In the first place, E F, being parallel to A K (not shown), has the required batter. In the second place the distance CF, determined as explained, satisfies equation (1); for we have

$$\overline{CF} = \overline{LD} = \sqrt{\overline{LC}^2 + b^2} = \sqrt{(\overline{CK}\tan 30°)^2 + b^2}$$
$$= \sqrt{(\beta h \times \frac{1}{\sqrt{3}})^2 + b^2} = \sqrt{\frac{\beta^2 h^2}{3} + b^2}$$

I hope this "rule of thumb" will be found simpler than Mr. Trautwine's. Yours very truly,

Antonio Llano.

International Correspondence Schools,
Scranton, Pa., June 26, 1900.

Uniform Municipal Accounting in Wyoming.

Sir: I have carefully read the article on "Progress Toward Uniformity in Municipal Accounting," in your issue of July 5. I am delighted that you have taken up this subject and believe that your efforts will aid materially towards accomplishing and bringing about a system of uniformity in accounting throughout our land.

This, in turn, will bring about advantages to the taxpaying public and the people at large. The subject is one in which I am deeply interested and to which I have for almost eight years devoted my entire time and energies in this state.

Wyoming's State Examiner law, is, I believe, the most advanced of any law looking towards uniformity and supervision of public accounts of any state in the Union. The office is a constitutional one and while the law was, as originally enacted, a creditable one, yet it has during my incumbency of the office been so amended as to meet with almost every condition that may arise in our state in relation to the proper handling of public affairs. We have experienced the benefits that have been derived and any recommendation that might be made toward the further usefulness of the office would be promptly enacted.

It was not at first contemplated that the officer in charge would inquire into every detail of public accounts, but rather that he would make brief examinations, and, in fact, this was the policy pursued by the first examiner, my predecessor.

Upon assuming the duties of the office in 1892 I determined to take up all matters coming under my supervision in detail and have since pursued this policy. I believe that at this time Wyoming enjoys the most econ-

...al government in state and county affairs of any ... It is **true that we have a small valuation**, but this is one of the reasons why we should practice economy. ... state and county governments are conducted upon ... business principles and for what we believe to be the best ... interests of our citizens. The county governments cost, in 18... approximately $412,000, while in 1899 they cost ap... proximately $295,000. In 1892 there were but two counties ... upon an approximate cash basis; in 1899 every county was ... upon an approximate cash basis. In other words, the ex... penses of the government were paid from the revenues ... of the current year, and no expense created that would ... not be discharged from such funds.

... some of the counties there would not be funds on ... hand at the time of the creation of the expense to dis... charge it immediately, but as the revenue came in from ... taxes and other sources, the obligations were discharged ... and at the close of the year each county had a surplus ... against which there were no obligations.

Furthermore, we have a superior government and derive ... more actual benefits under the decreased expense than ... obtained under the conditions as they existed prior to ... 1892. These conditions have been followed by decrease in ... the rate of taxation for governmental affairs, and an in... crease in the rate of taxation for public school purposes, ... and we congratulate ourselves upon the efficiency of our ... schools. Notwithstanding the increase in taxation for ... schools the levy as a whole is less than it was a few ... years since.

I do not maintain that these conditions are all the direct ... result of the efficient supervision of public accounts and ... public affairs, but believe the office has been of much ... assistance from a supervisory and advisory standpoint.

In every examination all business conducted in an of... fice since the previous examination was made is carefully ... inquired into. Each item, whether great or small, is ... checked into the cash record and from that office to the ... final depository. Every item of expenditure is personally ... handled and checked and every column of figures carefully ... footed and finally summarized. This involves much labor, ... but it is always a satisfaction to know that the examina... tion when complete has been thorough.

These are but a few of the matters that enter into the ... duties of the officer in this state and a few of the results ... that have been effected, partly at least, through the opera... tion of the law.

I have had but little time to give to municipal affairs, ... the work in state and county affairs having increased very ... rapidly. We hope to have sufficient assistance very soon ... to enable the office to exercise the same supervision over ... municipal and school affairs as are now exercised in state ... and county governments.

If a conference of examiners, engineers and leagues and ... all persons thoroughly interested in the subject could be ... had, I am confident they could arrive at conclusions, ... which, enacted into laws, would be of great benefit to the ... people and establish a uniformity in accounting that would ... not be limited to but one state, but to many.

I take pleasure in sending you under separate cover, a ... copy of our law. Very respectfully yours,

Harry B. Henderson, State Examiner.

Cheyenne, Wyo., July 17, 1900.

The Visit of the American Mechanical Engineers to the Creusot Works of Schneider & Co., France.

Sir: In connection with the visit of the American Mechanical and Civil Engineers to Paris, a series of side trips were arranged by interested parties. One of the most important of these was a visit to the great steel works of the Schneider Company at Creusot. The party invited by Mr. Schneider, consisted of Mr. Bonvillain, a prominent French engineer and representative of the Q. & C. Co., of Chicago; Mr. Wallace, President of the American Society of Civil Engineers; Mr. John Thompson, President of the Engineers' Club, New York; Mr. Robert W. Hunt, of Chicago; Mr. John J. W. Reynders, Superintendent of Bridge Department, Pennsylvania Steel Co.; Mr. Lawrence T. Braine, President of the Continuous Rail Joint Co.; Mr. S. L. Hills, Paris representative of the Q. & C. Co., Chicago, and Mr. J. J. Swann, of the Ingersoll-Sergeant Drill Co., New York. The party left the Gare de Lyons at 2 p. m., July 16, in a special saloon car attached to the regular P. L. M. express. No stop was made until Laroche (Yonne) was reached, where there was a wait of five minutes.

The day proved ideal, for the sun was shining and trees and fields alike presented a beautiful variation of green, brown and yellow which, viewed from the windows of the comfortable special car, presented a never-to-be-forgotten panorama. The succession of well-cultivated fields and red-tiled houses, always surrounded by hedges or verdure of some sort, gave outward evidence of prosperity. The streams, or, as we would say, brooks could nearly always be traced by the line of tall and wonderfully straight and slender poplars which zigzagged across the lowlands like a row of gigantic green feathers.

Our second stop was made at Dijon where, in the absence of dining cars, it is customary to rest for about 25 minutes to answer the calls of the inner man which, by this time, were not to be ignored after the influence of braving country air ladened with the odor of trees and green pastures and yellow fields of ripening grain. Soup was waiting at each of the half hundred places in the quaint station, and as the plates were rapidly emptied, new ones with successive courses took their places. The epicures of the party, in discussing the event afterwards in the secrecy of our car, voted the soup cold; the entrée, good; the rotis, excellent; the légumes, good; the desert, fine, and all in all the best quick dinner they had ever tasted for 4 francs.

At Chagny we were dropped off the regular train and the car run up by man power on a transfer table and slid across for about 100 ft. to the branch track running to Creusot. At the end of an uneventful ride in the darkness we clambered out to be met by M. Vannier, Ch. Engr. of the Steel Works, and carriages to escort us to the hotel.

Our tour of inspection of the great works began after a mixture of French and American breakfast which certainly upset all standard ideas in that hotel, for it began in the orthodox way with coffee and rolls and wound up with eggs and fruit.

Entrance to the works was a bit complicated owing to the existence of a strike in the rolling mill department, but we were expected, and our cards passed us into the inner sanctum sanctorum. After a brief chat, half English, half French, we were put in the hands of M. Ballereau, who was to act as our guide throughout the works. Mr. Saladin, Chief Engineer of the Creusot Works, also joined us. We first inspected the testing department, under the charge of Mr. Bermont, Engr. of the department, where there are two tension-testing machines: one, an old style beam and weight type, and the other a hydraulic type, employing a screw for first adjustment and a hydraulic cylinder for producing the actual load. Tension indications were obtained from a diaphragm manometer. The test piece was held by a split collar which rested against the shoulder of the piece. Balanced pull is obtained by a system of universal joints. The machine is simple in appearance and apparently satisfactory in operation.

The locomotive erecting shop came next. Here a fair idea was afforded of the anatomy of a French locomotive, as there were several in various stages of completion. Our first evidence of the use of hand work, where portable tools are used in our country, was afforded here. This impression grew as we passed through the works; but in this respect, the cheapness of labor must be considered. Further on was one of the machine shops doing a somewhat diversified class of work, from turning up prepellor blades to making tires for field artillery carriages and trunnions for large marine cannon.

Still further on, in a rather new portion of the establishment, the large vertical engines for the Metropolitan Railway of Paris were in course of construction; likewise several large marine engines. In the latter, cast steel is largely used for the sake of lightness. The cast-steel frames and base plates are unquestionably lighter in section, but, of course, not as smooth and finished as cast-iron. Some of the large cast-iron cylinders seen here were excellent examples of the art of founding. The stock yards, other machine shops, the boiler shop and yard brought us to the gate and breakfast hour, 11 o'clock, at the same time.

The afternoon was well spent in the forge shop, armor plate mills and the rod mill. All three of these compare rather favorably with our own practice. Bethlehem, it will be recalled, obtained some of its armor-plate machinery from Creusot several years back.

The forge shop, under the direction of Mr. Ronty, has two large hammers, one built in 1876, a 3,000-ton Whitworth hydraulic forging press, and the necessary cranes for handling the enormous masses which are worked up into shafts or guns. There is also a 10,000-ton Whitworth hydraulic press in the open-hearth department and a 2,000-ton Tennett-Walker press furnished by Mr. Bonvillain. The armor-plate dressing or finishing department was in full working order, most of the machines being large, slowly-moving, circular metal saws used to trim up the edges of the plates. A fair idea of hydraulic plate bending was afforded by several 3-in. sponson plates, which had been twisted into a decidedly "S" shape.

The tempering department is particularly well equipped for both gun work and armor plates. The furnaces are vertical and all open out into the pits in which are the oil baths. Cranes, overhead, make the handling of plates or tubes an easy matter. In this and the forging and rolling departments, one forms some idea of why armor plate costs so much to produce. A novelty in the way of saving defective plates was noticed, which it would seem could be employed in the United States. Briefly, it was nothing more or less than cutting out the defect as one would take a spot out of an apple, and then re-rolling the plate to a lesser thickness.

The rolling mill, of which Mr. Hennibique is Chief Engineer, which came next in order, presented so far as a rapid general survey would show, practically no difference from ordinary practice with us. It is interesting in passing to note that plates from the thinnest to the heaviest armor plate are turned out of this one building, and, indeed, the same is true of rods and bars. They do not, however, make rails of anything but the smallest sections. These mills, as already stated, are shut down owing to a strike, but one could readily see how 2,500 men, the usual force, could find working room in the large building.

Passing on, the stock room for beams and rods was next encountered. This also is a sizable place, notwithstanding the fact that only a very small amount of any one size is carried on hand. An excellent idea noticed, and one which could be imitated with advantage by others, is the stacking frames. These are vertical with about one-third below the floor line. Outside of this building the stock of small rolls is neatly and most conveniently arranged in vertical piles by means of guides made of angle-irons set vertically in the ground.

The gun shop and other smaller departments were not visited owing to the shortness of the time, mention must, however, be made of the immense pump used for draining of the coal mines which honeycomb the entire ground under the works. This pump, erected in 1863, has a steam cylinder, 13 ft. stroke and 84¼ ins. in diameter. It is a beam engine with an immense steel beam under the engine-room floor. Instead of a fly-wheel, the far end of the beam is simply loaded with a very large weight. The lift is about 1,200 ft. and, for purpose of inspection, there is a vertical geared winding engine, which lowers a man and bucket down the pump-shaft once each day.

As the afternoon was well advanced, further visits were postponed, and visitors and guides made for the "Club," quite a pretentious affair, presented by Mr. Schneider for the benefit of the officials of the company and inspectors and engineers temporarily resident at the works.

Later in the evening there was a most enjoyable dinner at the club house which lasted until time to rush for the train. Mr. Saladin, Chief Engineer of the Creusot Works, acted as toastmaster for the company, while Captain Hunt made the response for the visitors. Hasty good-bys were followed by a rapid drive to the station, where our special saloon car was coupled to the train and we were soon flying towards Paris. There being no porter to make up berths, it was necessary to turn to and spread sheets. The seats were arranged for pulling down and mattresses and bedding were found hidden in out of the way places. Things were understandable except the sheets, which were made in the form of a bag. The modus operandi of these proved beyond the ken of the combined engineering talent of the party. Fairly tired and quite sleepy, we were rolled, yes, literally rolled in sheets and working hard to get asleep, but the constant and violent side swaying of the car prevented anything but the most troubled and often interrupted repose, during which we were rapidly hurried towards Paris and the bustle of the Exposition City, where we landed at about 7 a. m., thus ending a most enjoyable and instructive trip.

Very truly yours, J. J. S.

Paris, France, July 21, 1900.

TRACK MAINTENANCE BY CONTRACT.

The practice of having railway maintenance-of-way work done under contract has, we believe, never been followed in this country, but has been somewhat extensively followed in some of the European continental countries. This subject is dealt with briefly in a report on "Maintenance of Way on Lines with Heavy Traffic," prepared for the coming meeting of the International Railway Congress at Paris by Mr. J. W. Post, Divisional Chief Engineer of the Netherlands State Railways. The contract system formerly prevailed even on lines with heavy traffic, but has now been largely abandoned, for the following reasons given by different roads which have finally abandoned the system: (1) The continual increase in the number of trains; (2 the difficulty in drawing up a satisfactory schedule of prices; (3) the difficulty of controlling the operations; (4) the inferior quality of contract work, in spite of strict supervision; (5) the uncertainty in assigning the various items of work to the proper heads in the schedule of prices; (6) the complications arising in making a rational distinction between the day's work performed by the laborers for the engineering department and that done by the contractor.

The Royal Dictorate of German Railways (Munster Division) has certain work carried out by the engineering department, but also gives out under contract the work of maintenance, with a guarantee of the quality of the work. It is stated, however, that work done by the railway employees is superior to contract work, and that the latter would be discontinued if a sufficient number of men could be obtained. The Austro-Hungarian State Railway, however, which formerly carried on all maintenance work exclusively by its own men, now employs a mixed system. From October to March, the railway maintenance forces maintain the track entirely, but from April to September special auxiliary gangs are engaged, who are paid on a schedule of prices. The admin-

istration of this railway system presents the following advantages of letting out the maintenance work by contract:

(1) The staff is in a better position to form an opinion of the work to be carried out, and when work done by contract is measured up for payment the inspection is more strict than in the case of work carried out by the engineering department.

(2) The work is better done, because the men are afraid of having to do it over again, if it is scamped.

(3) Contract work tends to produce a better class of workmen, as idlers and incompetent men are eliminated under this system.

THE INFLUENCE OF STRUCTURE ON THE WEARING POWER OF PAVING BRICK.

The National Brick Manufacturers' Association has issued the first report of its "Committee on Technical Investigation," as noted elsewhere in this issue. The committee consists of the following members: D. V. Purington, Chairman, Chicago; C. A. Bloomfield, New York city; W. D. Richardson, Shawnee, O.; Anthony Ittner, St. Louis, Mo.; Prof. Edward Orton, Jr., Secretary ex-officio, Columbus, O. The first work of the committee was an investigation of the relation between structure and wearing power of paving brick, which study was entrusted to Professor Orton and Mr. A. V. Bleininger. The conclusions of the monograph prepared by these gentlemen are as follows:

While it is by no means intended to give the impression that the preceding investigations are considered to be so complete and final as to preclude the need of elaboration or revision, it is thought that the work done is not only by far the most searching investigation which has as yet been made on this subject, but also that its principle conclusions are established with reasonable security.

Further confirmation is much needed and desired, and it is urged upon paving-brick makers to use the experimental facilities of their own plants in the elaboration of such tests as the preceding, on a scale which is impossible in laboratory work. Until the execution of a number of such tests by competent observers has demonstrated the faultiness of this work, the following propositions may be regarded as established:

Side-Cut Against End-Cut.—(A) A clay, being made into paving brick by the stiff-mud process, is more likely to develop its best structure and its greatest resistance to abrasion when made by side-cut machinery, rather than end-cut.

(B) But the peculiarities shown by clays are specific, and not generic, and it is not believed to be possible at present to determine which process should be used in any given case except by actual trial of both processes under the same conditions of test.

Effect of Repressing.—(C) Makers of paving brick should assume that their plain wire-cut brick are superior to the repressed brick until they have proven, by careful comparison under identical tests, that the assumption does not hold good in their case.

(D) If repressing is necessary to meet market conditions, the maker should perform the operation so as to cause a radical breaking up of the auger machine structure, and the production of a new and characteristic structure due to repressing. If this is done, the probabilities are that no falling off in quality will occur, and actual gain in strength may frequently result.

Size and Shape of Paving Brick.—(E) The proportions of paving brick are shown to be of greater importance in its resisting power to blows and strains than the actual size. Large size and faulty proportions will produce a brick more likely to fail in use than small size with proper proportions. The most convenient basis for comparison is the ratio:

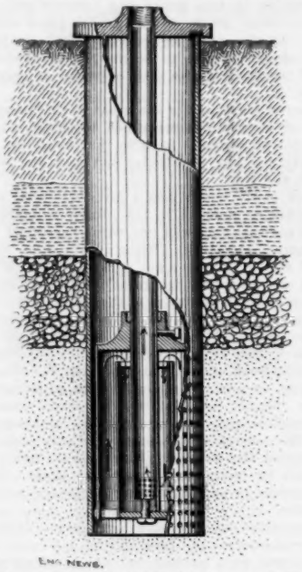
$$\frac{\text{Thickness}}{\text{Length} \times \text{Breadth}} = \text{"coefficient of thickness."}$$

This coefficient should have a numerical value of not less than 0.1, and bricks should not be made of such lengths and breadths that, with a thickness of 3½ ins., their coefficient falls below the above value.

A COMBINED STRAINER AND SAND TRAP FOR DRIVEN AND ARTESIAN WELLS.

The accompanying illustration shows a supplementary strainer and sand trap which has been applied to a number of driven wells at McKeesport, Pa., to keep sand out of the pumps. The water enters through the perforations in the bottom of the outer casing, passes downward between this casing and a second cylinder with a closed top, then up between this second cylinder and a third one, going over the top of the latter, down and into the perforations at the bottom of the suction pipe, or well proper. The greater relative area of the perforations in the outer cylinder results in a low velocity of the water passing through, thus reducing the tendency for disturbance of the sand, while the subsequent course of the water is designed to prevent the passage of any sand to the suction pipe.

The device has been patented* by Mr. Harry Etheridge, of McKeesport, Pa., to whom we are indebted for information regarding it. It was first used, as we understand it, on a well or wells belonging to the McKeesport Light Co., where it was placed in December, 1897. Satisfactory reports of its success there led to the equipment, in September, 1899, of four wells belonging to the waterworks of McKeesport. Other wells at this plant



Sectional View of Well Strainer and Trap.

are now being similarly equipped. These wells, of which there are ten, are sunk near the Youghiogheny River, the original source of supply. The river, Mr. Etheridge states, has become so badly polluted as to make its abandonment necessary, or advisable. Mr. T. H. Verner is superintendent, and Mr. J. M. Kinkaid is mechanical engineer, of the city water plant of McKeesport.

THE TRANSCONTINENTAL TRIANGULATION ALONG THE 39TH PARALLEL.

In Bulletin No. 38, of the University of Wisconsin, Mr. John F. Hayford, Chief of the Computing Division of the U. S. Coast and Geodetic Survey, briefly outlines the results of triangulating across 2,600 miles of the United States; from Cape May, on the Atlantic Ocean, to Point Arena, on the Pacific Coast, north of San Francisco. The purpose of this survey along the 39th parallel is to unite the surveys of the two coasts; to serve as a survey of last resort in adjusting errors incident to more approximate methods, and to use the results in connection with similar surveys, in determining the figure and size of the earth.

Ten base lines were employed to fix the lengths of the various lines of the Transcontinental Triangulation. The first, the Kent Island base, on Chesapeake Bay, was measured in 1844 with the Hassler base apparatus. This consisted of four iron bars, each 2 m. long, placed end to end in a box, so as virtually to form one bar. Thermometers were used to determine the temperature of the bars; and the microscope was employed to determine contact. The probable error in this base is about 1 in 130,000 parts of its length.

The American Bottom base, in Illinois, a short distance east of St. Louis, was measured in 1872. For this purpose the pair of base bars, known in the Survey as Nos. 1 and 2, were employed. The measuring bar proper was in each of these an iron rod 6 m. long, with the temperature determined by a single thermometer. The bar ends were referred to each other by a device known as a contact slide. This base was measured but once; and the estimated probable error is 1 in 350,000 parts of the length.

The Olney base, near Olney, Ill., was measured by the U. S. Engineers in 1879, as part of the Lake Survey triangulation. Here, the Repsold apparatus was used; consisting essentially of a bar of steel and one of zinc, each 4 m. long, rigidly fastened together at the middle point. The coefficient of expansion of the zinc was 2 times that of the steel; and the difference of expansion between these metals served to give the temperature of the steel measuring bar. The computed length of base was thus independent of the reading of the mercurial thermometer. Experience proved that this bi-metallic apparatus was liable to several errors most to be feared in base measurements. The probable error of computed length in this base is about 1 in 740,000 parts.

The El Paso base, in Colorado, was measured in 1879 with the 6 m. contact slide base bars, known in the Coast and Geodetic Survey as Nos. 3 and 4. These steel measuring bars were protected by wooden casing, and mercurial thermometers were used. The probable error is 1 in 750,000 parts.

The Yolo base, in the Sacramento Valley, California, was measured in 1881. In the new apparatus employed, each measuring bar was composed of steel and zinc, rigidly joined in such a way as nearly to compensate for changes of temperature. Some of the same difficulties were encountered as in the Olney base; and the estimated probable error is 1 in 1,100,000 parts.

The Holten base, in southern Indiana, was measured in 1891 with both steel tapes and base bars. The bars were steel with contact slides; with mercurial thermometer to determine temperature. The tapes were 100 m. long, supported at intervals of 10 m., and the temperature was determined by thermometers, and assumed to be that of the surrounding atmosphere. The tape measurements were made at night. The length of the base, as derived from the tape measurement, differed from that of the bars as 1 in 320,000 parts; and the estimated probable error of the mean result is 1 in 710,000 parts.

The St. Albans base, in the Valley of the Great Kanawha, W. Va., was measured in 1892 with the same tapes used on the Holten base. The estimated probable error is 1 in 1,100,000 parts. The Salina base, near Salina, Kan., was measured in 1896, with the bars used on the Holten base. The estimated probable error is 1 in 1,100,000 parts.

The Salt Lake base, on the eastern shore of the Great Salt Lake, was measured in 1896 with a new apparatus known as the duplex base bars. Each consists of two measuring bars, one of brass and one of steel, supported side by side and parallel to each other in the same supporting and protecting wooden tube. These two bars are not connected; but the position of each is referred to the other by verniers on the brass bar and scales on the steel bar. In this apparatus both the bi-metallic method and mercurial thermometers are used to determine temperature. As a test of the thermic behavior of the apparatus is thus furnished by each triple measure of a section of the base, independently of any other measures, measurements made with this duplex apparatus are entitled to a much higher degree of confidence than those made with other forms of apparatus here referred to. The estimated probable error of the length of this base is 1 in 1,600,000 parts. The three lengths for the base, given by the steel bars and thermometers, by the brass bars and the thermometers, and the brass and steel bars used conjointly, all agreed within less than 1 in 2,000,000 parts.

The Versailles base, near Versailles, Mo., was measured in 1897 with a 50 m. steel tape, similar to that used on the Holten and St. Albans bases. But this tape was supported at 25 m. intervals, thus saving cost in preparation, and the thermometer was fastened rigidly to the tape. The estimated probable error is 1 in 960,000 parts.

In making the Salt Lake and Yolo measurements a shed was used to protect the apparatus from the direct effect of sun and wind. This was a wooden frame, 50 ft. long, 12 ft. wide and 9 ft. high; bolted together, covered with canvas and mounted on four wheels, and weighing 1,500 lbs.

As would be expected, a great variety of instruments were employed, between 1844 and 1897, in measuring the angles; the principal theodolites varied in size, from those having a 39-in. graduated circle to a 12-in. circle in the later ones. The

*Patent No. 600,269, dated Aug. 16, 1898.

final number of observations or series observed was in some cases as small as 24, and in other cases as large as 126; 33 and 34 are the numbers occurring most frequently. The largest average closing error in any of the 21 sections, into which the 39th parallel triangulation has been divided, is 2" of arc; and the smallest is 0.6". The average for the whole parallel is 1.1" in arc. Many of the lines were more than 100 miles long; and observations were secured in both directions over a line 182.7 miles long. These observations were made upon heliotropes; a 3-in. square mirror for the 100-mile lines, and 6-in. square for the 182-mile line. The signaling mirrors were from 8 to 12 ins. square, and their light was often visible to the unaided eye at distances of 100 to 150 miles, in the clear atmosphere between Pike's Peak and California. Observing towers were used to a maximum height above the ground of 152 ft.; the last was at Green Station, Indiana.

The triangulation along the 39th parallel is followed by a line of precise levels, which is now complete from the Atlantic Coast to Denver, Colo., and to Cheyenne and Rock Creek, Wyoming. This line is being rapidly extended westward to the Pacific.

FINAL REPORT OF THE SPECIAL COMMISSION ON THE CHICAGO DRAINAGE CANAL.

The Act of 1889 of the Illinois Legislature, under which the construction of the Chicago Drainage Canal was undertaken, required that before the canal was opened it should be inspected by a special commission on behalf of the State of Illinois, which should certify to the Governor that the work had been carried out in accordance with the Act, in which case the Governor should authorize the admission of water and sewage to the canal. "The said commission shall take as their datum line for the survey the datum established by the Illinois & Michigan Canal Trustees in 1847, and shall make such examination and surveys of the Chicago River, and of the channel or channels authorized by this act as shall enable them to ascertain whether said channel is of the character and capacity required by this act." The special commission was appointed by the Governor, John R. Tanner, in May, 1899, and consisted of Messrs. Isaac Taylor, of Peoria; Al. F. Schoch, of Ottawa, and John Lambert, of Joliet. Mr. Desmond FitzGerald, M. Am. Soc. C. E., Department Engineer of the Metropolitan Water Board of Boston, Mass., was appointed Chief Engineer. An abstract of the preliminary report made by the commission was published in our issue of Dec. 7, 1899, and the present article is prepared from the final reports of the Commission and its Chief Engineer, recently issued under date of June, 1900.

The engineering department took cross sections of the channel at intervals of 800 ft. throughout its entire length, from Robey St., Chicago, to Lockport, 28 miles. From these it was found that the channel meets the requirements of the Act as to capacity and velocity of flow. The alluvial portion has a capacity of 360,000 cu. ft. per minute and a depth of over 14 ft., with a current not exceeding three miles per hour. The rock portion has a capacity of 600,000 cu. ft., a bottom width of 160 ft., and a depth of over 18 ft., with the same current. The Act required a flow of 20,000 cu. ft. per minute for each 100,000 of population in the district. From censuses and other sources of information, the engineer found that the population of the city was 1,926,000, with over 1,800,000 within the Sanitary District. This would require a continuous flow of 360,000 cu. ft., for which the channel has sufficient capacity. In the Chicago River, from Bridgeport to the lake, cross sections were taken 200 ft. apart, and were verified by comparison with the surveys of the government engineers. With the dredging completed and with the other improvements made by the Sanitary Trustees (including the by-passes at Adams St. and Van Buren St., which add about 1,000 sq. ft. to the cross section at these points) the Chicago River is within the requirements, having a capacity of 360,000 cu. ft. per minute at a current not exceeding three miles per hour.

The bridges are within the requirements of the Act, which provides that they must not obstruct the navigation of the channel, but the Sanitary Trustees are not required to operate them as movable bridges for seven years after the opening of the channel (January, 1900) unless the needs of navigation on the Desplaines and Illinois rivers, when connected with the channel, shall require it sooner. The controlling works at Lockport, on the west side of the lower end of the canal, are well adapted for their purpose. There is a bear-trap dam 160 ft. wide; and also seven sluice gates 30 ft. wide, with provision for eight additional gates. The tail race from the controlling works to the Desplaines River, and the excavation in the river to the upper basin in Joliet are found to be of proper capacity. The Act provides that the Sanitary Trustees "may" remove obstructions in the Desplaines and Illinois rivers when necessary to prevent overflow or damage, and "shall remove the dams at Henry and Copperas Creek, in the Illinois River, before any water is turned into the drainage channel." The Trustees have been willing and ready to comply with this provision, but the Canal Commissioners, feeling that the removal of the dams would destroy the navigation of the Illinois River below La Salle, and taking the position that the removal of the dams was within their jurisdiction, commenced legal proceedings to restrain the Trustees from removing the dams. The lower court decreed in favor of the Trustees, and the Canal Commissioners then took their case to the Supreme Court of Illinois, in whose hands it now rests. The Special Commisson reports that on the advice of its attorney it did not wait for the decision of the Supreme Court before reporting to the Governor in favor of granting a permit for the opening of the canal. On Jan. 17, 1900, the Commission telegraphed its findings to the Governor, who at once issued the permit, and at 11:15 a. m. of that date the bear trap dam was lowered, and the water already in the canal allowed to flow into the valley of the Desplaines River.

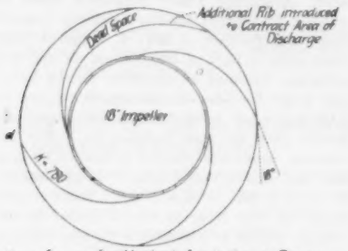
Mr. FitzGerald, in his report, gives a general description of the canal and its works, in the course of which he calls the Chicago River "an elongated septic tank, filled with decomposing organic matter." The works include four important sections: (1) The deepening ad widening of the river from its mouth to Robey St., 6 miles; (2) the construction of the drainage canal proper, from Robey St., at Bridgeport, to Lockport on the Desplaines River, a distance of 28.05 miles, including the controlling works; (3) the diversion of the Desplaines River, with new channels and levees separating it from the drainage channel; (4) the tail race and new river channels from Lockport to Joliet. In addition to these, the Sanitary District has an interest in the 20-ft. 39th St. sewer, now under construction. This will be 12,070 ft. long, of which 10,000 ft. will be built as a tunnel, under air pressure, and 2,070 ft. at the west end in open cut. It will not only serve as an intercepting sewer (Eng. News, April 21, 1898), but is intended to connect the lake with the south fork of the Chicago River, near the Stock Yards. Under an agreement between the city and the Sanitary District, the latter is to erect and maintain a pumping plant on the lake shore to increase the flow in the conduit in order to keep pace with the dilution of the sewage, as required by law, as the population of the district increases.

It has already been stated that the Sanitary District Act provided that the special commission should take as the datum for its survey "the datum established by the Illinois & Michigan Canal Trustees in 1847." This level has always been taken as the low water mark of Lake Michigan, but in 1895 the lake receded 1.01 ft. below the level of 1847. Mr. FitzGerald made careful investigation as to the original datum, but could not find any authority for assuming that it was established by the Canal Trustees in 1847. The records of the Canal Office, of the State, and of the city, show no legal establishment of a datum in 1847. The precise levels of the Sanitary District start from a bench mark established in 1882 on the sill of the canal collector's office at Bridgeport, referenced from a bench mark on the coping of the old lock of the Illinois & Michigan Canal at Ashland Ave. This lock was built in 1847, and tradition has connected its construction with the low water of that year. Part of this lock is still standing. There is sufficient evidence to prove that Chicago datum is not more than 0.18 ft. higher than that used by the canal engineers in building the lock, and it may therefore be taken as the datum representing low water in 1847.

Investigations as to the slope of surface and velocity of current in the Chicago River, based upon measurements made by Mr. Thomas T. Johnston, Assistant Chief Engineer (and now Consulting Engineer) for the Sanitary District, during the great freshet of May 6, 7 and 8, 1892, showed that with a flow of 360,000 cu. ft. per minute, the average velocity of current would be 1.33 miles per hour for the entire length of the river, and 1.63 miles per hour for the narrowest stretch between 18th St. and Halsted St. The permissible current must not exceed 3 miles per hour. With the flow above noted, the total fall from the Lake to Robey St. is 2.995 ft. Measurements were made of the flow in the Illinois & Mississippi Canal, which is parallel with the drainage canal for part of its course. Experiments were also made with the rate of flow of concentrated sewage (which forms the flow of the canal) and clear water, which showed that no allowances were to be made on account of the character of the fluid. In the drainage canal, there is a fall of 5.65 ft. from Robey St. to the controlling works, and the earth banks are caving badly, but the alterations in form have not yet materially affected the capacity. Cross-section surveys were made of the canal, and showed that the earth sections had practically the capacity of 360,000 cu. ft. per minute, as required by law, with an average velocity of 1.27 miles per hour. The rock sections have a capacity of 680,000 cu. ft, per minute (or 882,000 cu. ft. with a lower coefficient of roughness), as compared with the required capacity of 600,000 cu. ft. With the higher capacity, the velocity would be 2.8 miles per hour. The depth of water will not be less than 21.4 ft. With the channel frozen over to a depth of 22 ins., displacing 20 ins. of water, the flow would be far below the requirements, being from 178,860 to 266,160 cu. ft. per minute in the narrow earth sections, 352,680 to 504,500 cu. ft. in the wide earth sections, and 396,840 to 504,480 cu. ft. in the rock sections. As a feeder to the drainage canal, the 39th St. tunnel already referred to, will have a capacity of 85,164 cu. ft. per minute, with a flow of 360,000 cu. ft. in the river. To discharge 120,000 cu. ft. per minute, which has been estimated as the maximum capacity of the tunnel, will require a head of 6.37 ft., which can only be secured by means of the pumps to be erected at the west end.

In regard to the flow from the controlling works to the upper pool at Joliet, and from this pool down the Desplaines River, Mr. FitzGerald states that the Sanitary District is now making provision for discharging 25,000 cu. ft. per second at Joliet, 13,000 cu. ft. passing over the dam (272 ft. long) across the pool, and 12,000 cu. ft. through gates which it is proposed to build in connection with the tail race on the side of the channel. The depth over the dam would be 10 ft. and 6 ft. for flows of 25,000 and 13,000 cu. ft. The propriety of building a fixed dam across the narrow channel in a position like that at Joliet may well be questioned from an engineering point of view, but the position and height of this dam were fixed by a decree of the court. Mr. FitzGerald has suggested, however, that spillways, with a capacity of 12,000 cu. ft. per second should be built in the wall which is to be erected on the side of the channel in connection with the water power development. Of the maximum flow of 25,000 cu, ft. at Joliet, it is assumed that the drainage canal will furnish 10,000 cu. ft. (as the law requires a continuous flow), leaving 15,000 cu. ft. to be contributed by the Desplaines River. The observations on the freshets in the river indicate a freshet yield of 16,766 cu. ft. per second (with a collection of 0.79-in. in 24 hours), but Mr. FitzGerald considers that a very much larger freshet than this may result from the combination of a warm rain with snow on the ground. With such a flow, the provision for waste at the Joliet dam would be en-

tirely insufficient, and the water would rise high enough to flood certain portions of the city of Joliet. It seems possible that a freshet might occur which would not pass down the channels provided in the diversions of the Desplaines River, especially if accompanied by serious ice jams, in which event the drainage canal might be overflowed and the Chicago River made to discharge into the lake. A more careful study of this subject is recommended, and it is suggested that it



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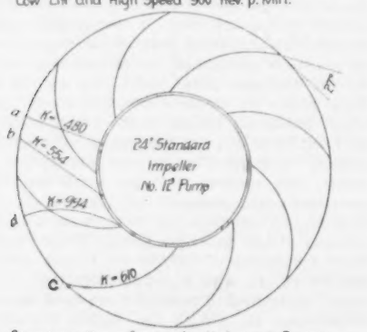


Standard Vane Curves for Horizontal Pumps
Speed = 10 $\sqrt{h}$.

Fig. 1.—Diagrams Showing Vane Curves of Centrifugal Pumps.

may be practicable to provide for a cut-off or diversion of a portion of the Desplaines watershed to the lake, as already proposed by Mr. Lyman E. Cooley and others.

THE RAILWAYS OF CAPE COLONY at the end of 1899 aggregated 2,661.75 miles, with 32.75 miles of double track, but owing to the war about 1,026 miles of this system were cut off from operation. In spite of the war the net earning were over 4½% on the capital, almost as much as in 1898, owing to the military traffic. Every effort was made to meet the military requirements of the situation, the engines being worked to their utmost capacity, and new locomotives and rolling stock will soon be urgently needed. Old 45-lb. rails are being relaid with 60-lb. rails, and 85-lb. and 100-lb. rails are also being used to a small extent. Fractures of splice bars are numerous on the 60-lb. rails, owing to the high speeds and heavy axle loads of the engines. The old wrought-iron ties are being replaced with wooden ties, and vulcanized native pine ties are to be tried. Owing to bad water in the up-country districts, the boiler repairs are expected to form a heavy item of expense, and some new engines with exceptionally large boilers are being provided for passenger service. The old style of European compartment car is giving way to the "saloon" type, a modification of the American type, and the transport service has shown the difficulty of carrying horses in the small four-wheeled freight cars on lines of 3-ft. 6-in. gage. The automatic vacuum brake is in general use on all trains. Lighting by acetylene gas has not been successful. The pipes became choked with carbon and a hard incrustation very soon formed on the burners. The company from which the plant was purchased operated it for some months, but the results were so unsatisfactory that the apparatus was discarded at all the stations where it had been in use. As to the transport service, Col. Howard Vincent has reported that while the Germans calculate that not more than 40,000 men can be fed upon a single line, in Cape Colony more than three times this number have been served, and that without grent interruption to the regular traffic.

TESTS OF CENTRIFUGAL PUMPS UNDER HIGH HEADS.*

The Kern County Land Co., through whose courtesy the writer is permitted to present the experiments hereafter described, has engaged in the pumping business on a scale of considerable magnitude, involving the use of some 600 or 700 HP., inclusive of the plants now in use, in course of construction, and in contemplation. The plants as first installed consisted of four wells, of 13-in. perforated casing to a depth of 70 to 80 ft., connected by common suction pipes to a No. 12 centrifugal pump set on the floor of a pit 8 to 12 ft. deep, the average depth to the standing level of well water. The pumps were belted to 30-HP. induction motors, actuated by three-phase current purchased from the Power Development Co., and when in operation draw the water down in the wells to a depth of 20 ft., making a total lift of 28 to 34 ft., and deliver a flow of 3 to 4 cu. ft. per second. Several stations a mile or more apart are operated by one attendant, not a mechanic, and the heavy belts and hot bearings soon proved a source of annoyance and expense, which led to the consideration of coupling the pump direct to the motor. During the wet years, or periods of heavy irrigation in the vicinity of pumping stations, the water level rises to a point that would submerge the band wheel of the pump, while in periods of extreme drought it may fall below suction depth. The natural relief from these difficulties was to resort to the use of vertical shaft pumps, direct-coupled to vertical-shaft motors, a plan which would make it possible to set the pumps as deep as might seem desirable, regardless of the height of the water line, while retaining the motor on the surface out of danger.

Such motors were not on the market at that time, but it was felt that the advantages gained by such an assembly would justify the development of suitable motors, if it proved possible to construct a pump which would give a satisfactory efficiency under the proposed conditions; viz.: inlet and outlet areas 10 ins. in diameter and a capacity of 5 cu. ft. per second when operating at 900 r. p. m. against a total lift of 30 ft.

As ordinarily constructed, the relation between the peripheral runner speed and the height of lift is expressed by the formula

$$d \times \pi \times \text{r. p. m.} = 60 \times 10 \sqrt{h},$$

where d = the diameter of the runner and h = the height of the lift, both in feet. In any given pump the expression $d \times \pi$ is, of course, a constant, and the speed varies with the square root of the head. Applying this formula to the case under consideration to obtain a suitable runner diameter for a constant speed of 900 r. p. m., we find that the resulting value of d is but little in excess of the specified area of the suction inlet and there would consequently be no room for the working vanes. Increasing the diameter of the runner to allow for the vanes necessarily increases the peripheral speed beyond ordinary limits. The question was submitted to several of the leading manufacturers of centrifugal pumps on the Coast without eliciting any marked desire on their part to undertake the problem otherwise than as an experiment at our expense, without any guarantee as to results, it being the commonly expressed idea that the high peripheral speed of the impeller would decrease the efficiency of the pump below the limit set.

Byron Jackson, a well-known pump manufacturer of San Francisco, was the only person who squarely accepted the specification that the manufacturer must guarantee a pump efficiency of 50%, the lift to be calculated from the sum of the static and frictional resistances as indicated by gages on suction and discharge pipes, failing in which the pumps were to remain the property of the contractor.

Four runners were delivered to us by the contractor for testing—all of the enclosed type—18 ins. in diameter, with vanes and waterways designed to suit the contractor's ideas of the changes from ordinary practice essential to successfully meet the new conditions. The vane curves and other dimensions are shown in Fig. 1. Two of the runners were made with 10-in. suction inlets for use in a standard No. 10 shell, which, as ordinarily used, is equipped with a 24-in. runner. Ports were cut through the runner from the suction side into a balance ring, cast in the bottom plate of the pump, to partly equalize the disproportion of area exposed to discharge pressure on the upper and lower side of the runner, but [illegible] construction an unbalanced excess of upward [illegible] which in operation proved to be downward. [illegible] pair of runners were cast with 8-in. inlets with [illegible] balance rings and intended to have the same degree [illegible] curvature, but through inadvertence were given [illegible] larger waterways than the No. 10 runners. An [illegible] was provided for these runners with a close-fit[illegible] joint between the throat of the pump and periphery of [illegible] runner, which made it possible to alter the thrust by [illegible] lowering the runner, the small, unbalanced [illegible] either up or down, being carried on collars work[illegible] balls running in oil in a vertical thrust bearing. When starting, the entire weight of the motor, shafting, runner and couplings rested on the ball bearings; but as soon as discharge pressure was obtained, most of this weight was counterbalanced by the up-thrust of the runner.

The pumps were set on the banks of the Kern Island Canal, and were connected with double 10-in. suction and a 10-in. discharge pipe, which delivered the water horizontally into a deflecting box shaped like the letter Y, with a hinged gate operating through an acute angle and opening and closing either outlet simultaneously. One outlet connected into a galvanized iron measuring tank, and the other allowed the discharge to waste back into the stream. The gate could be operated in a fraction of a second in admitting water to the tank. Time was taken with a stop-watch reading to ⅕ second, and the accuracy of the apparatus is indicated by the fact that in four successive measurements of the same flowage, the variation in time was only ⅖ second in 42 seconds, or something less than 1%.

The static lift was measured direct from the surface of the water to the center of the horizontal discharge pipe, and the sum of the static and friction resistance was obtained from the readings of a pressure gage on the discharge pipe above the outlet elbow graduated to a single pound, and a vacuum gage on the suction pipe graduated to inches. These gages were tested and found correct immediately before being used and the proper correction for relative vertical position was made. The observed data and calculations resulting from the tests are given in the accompanying tabulations, which are believed to be self-explanatory. There is included in this tabulation the test of two horizontal-shaft centrifugal pumps belted to induction motors, which may be taken as representative of the results obtained in previous installations. It will be seen from the efficiency shown that the contractor was entirely successful in his undertaking, but the marked improvement over the No. 12 pump with ordinary commercial runner is largely due to the disproportionate size of the pump with reference to available water supply. The insufficient water supply also led to the throttling of the discharge pipe to balance the runner; and, as will be seen from the column, "discharge pipe friction," this one item probably amounted to 10% of the expended energy. The belt-friction load probably amounted to another horse-power. Allowing for these resistances, the writer has reason to believe that the net efficiency of the standard runners when pumping their rated capacity is substantially the same as the special runners.

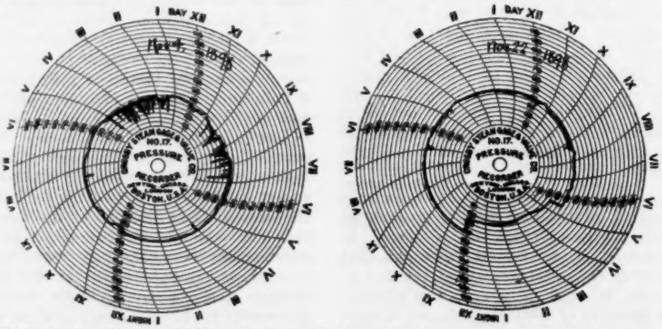


FIG. 2.—CARDS SHOWING VARIATION OF PRESSURE IN WATER-WORKS MAINS SUPPLIED DIRECT BY CENTRIFUGAL PUMP.

Granting that any centrifugal pump, with enclosed runners, may be adapted to high-speed work by suitable alterations of the runner, considerations of convenience and compactness in setting and operation, as well as economy in deterioration of belts and bearings, settles the question in favor of the vertical form, and, as a result of these tests contracts have been made for the manufacture of eight such pumps and vertical shaft motors, to be installed by the Kern County Land Co.

There is another outlet for power consumption by centrifugal pumps, which in Bakersfield, we owe to Mr. W. L. Dixon, engineer for the Electric Water Co. This company made its installation under his advice and now pump the entire domestic water supply of Bakersfield with two No. 4 centrifugal pumps direct-connected to induction motors. These pumps are situated about half a mile apart and discharge directly into 6-in. mains without any connection to a stand-pipe or tank, and maintain a by-

*Slightly condensed from a paper read before the Pacific Coast Electric Transmission Association.

drostatic pressure of 30 to 45 lbs. in the mains. As originally installed, one of these pumps discharged into a [illegible]-gallon tank at an elevation of 70 ft., from which the city supply was drawn by gravity. But it was soon found that better service was secured by pumping directly into the main, and at present the tanks are only used for reserves in case of temporary shut down of the power.

The local flour mill has been operated for some years past by means of a turbine, taking water from a gravity canal. This wheel has been connected up to a motor-generator, which, in case of accident, is run as a generator supplying current to the city pumps, or in case the water is diverted into other canals it takes current from the lines of the Power Development Co., and drives the mill. This constitutes the main reserve. The pumps regulate themselves, delivering under a remarkably steady pressure whatever quantity is called for by the draft on the pipes. If the draft increases, the volume pumped automatically increases as the pressure decreases; and if the draft were to cease entirely, by the closing of all cocks, the only effect at the pump would be to slightly increase the pressure. Fig. 2 shows sample sheets from the daily record of an automatic gage on one of the pumps, showing the normal working variations in pressure. The sudden fall in pressure for a small time interval, making almost a straight line on the diagram, represents the opening of a 6-in. valve to supply city sprinkling carts.

Certain interesting facts develop in connection with the operation of these pumps:

It was pointed out to the writer about a year ago by Mr. Edward S. Cobb, of San Francisco, that for constant speed the discharge of a centrifugal pump for any lift varies with the square root of the difference between the actual lift and the hydrostatic head created by the pump without discharge. If any centrifugal pump connected to a source of supply and to a discharge pipe of considerable height is put in revolution, it will be found that it is necessary to maintain a certain peripheral runner speed to hold the water 1 ft. high without discharge, and that for any other height the requisite speed will be very nearly as the square of the velocity for 1 ft. One of our most reliable mechanical hand-books states that the peripheral runner velocity in feet per minute required to hold water to any height without discharge is equal to $500\sqrt{h}$, basing the statement on experiments with the Appold pump, and making no qualification whatever as to the form of the vane, but treating the matter as though the constant 500 were suitable for any and all centrifugal pumps.

Other experiments prove, however, that the speed necessary to lift water to a given height with vanes of the form shown in Fig. 1 is approximately as follows: a, $481\sqrt{h}$; b, $554\sqrt{h}$; c, $610\sqrt{h}$; d, $780\sqrt{h}$; e, $394\sqrt{h}$.

It appears then, that instead of being a constant for all pumps, this number varies with the shape of the vanes; and as this means that different speeds are necessary to hold water to the same heights with these different forms of vanes, it follows that for any constant speed or lift there must be a form of vane more suitable than any other. It would seem at first glance that the runner which creates a given hydrostatic head with the least peripheral velocity must be the most efficient, but practically it is apparent from the tests heretofore described that the curvature of the vanes can be designed to suit the speed and lift without materially lowering the efficiency.

Consider any horizontal shaft centrifugal pump so connected to a source of supply that the level of the water would be maintained at the top of the runner, and provided with a vertical discharge pipe of greater height than the hydrostatic head which the pump can create at the speed at which it is to be operated, and of relatively larger diameter than the pump outlet. Let K = the peripheral speed per minute necessary to raise water 1 ft. without discharge with the form of vane used, and V any other peripheral speed per minute; then the height H, at which water will be held without flow in the discharge pipe, will be represented by the expression

$$H = \frac{V^2}{K^2}. \quad \text{(Fig. 3.)}$$

Now suppose an opening relatively small as compared to the diameter of the pump outlet to be made at a distance h below the level where the water is held. It is evident that following the well-known laws of flow through orifices, discharge will take place in proportion to the square root of $h - h_2$, multiplied into a suitable coefficient of efflux and the area of the opening, and that the height at which water is held will drop down in the pipe by an amount h_2 equivalent to the head necessary to overcome the frictional resistances created by the velocity of flow into and through the pump and orifice. If the entire height h is used in the ordinary formula for discharge,

$$D = A \times c \sqrt{2\,g\,h},$$

instead of the correct height $h - h_2$, then the reduction of head due to the creation of velocity, the resistance to entry of the foot-valve and of passage through the pipes and pump openings, will take the form of a lower coefficient, and the variations of this coefficient for different values of h and D will furnish some indication as to the variation of frictional resistances in the pump. In other words, c represents the ratio which the actual discharge for any head h bears to the theoretical discharge, and includes all sources of loss. If the resistances were constant at all heads, then for constant value of A, D would vary as the $\sqrt{h}$. But, if for any reason, the net sum of the resistances change, the coefficient will also change. The numerical value of the coefficient is of no importance, because it would be relatively large or small, depending on the size of opening used.

The experiments, of which Table II. gives the data and results, were made with a No. 4, standard pattern, horizontal shaft centrifugal pump, direct-connected to a 30-HP. three-phase motor and in daily use for water-works service. The discharge through a 6-in. pipe was connected into a measuring tank with a swinging elbow to waste-way. The pressure head was obtained by use of a valve on the discharge, the results being checked at several points by the use of a stand-pipe. It was possible to measure the suction depth directly, and the total resistances were shown by vacuum and pressure gages. The hydraulic data were taken with great care, equal in all respects to the tests heretofore described, but it was only possible to secure electric measurements on one leg, and the pump efficiencies are consequently valueless as exact statements, as there was no certainty that the load on the three legs was balanced. Nevertheless, they are of considerable importance in showing the relative efficiency which may be expected at different lifts in terms of the maximum efficiency for given speed. The total hydrostatic head was secured by closing the valve on discharge pipe and taking the sum of the heights represented by the vacuum and discharge pressure as the value of H. The valve was then opened far enough to lower the pressure 5 lbs. and the discharge was measured. Then another 5-lb. drop in pressure, and so on throughout the possible range of observation. The height h_1, representing the sum of static and frictional resistances at any point of discharge, has been calculated from gage readings for each point of observation. Also the value of the coefficient c has been calculated for the same points from the measured discharge, and with a value of $h_1 = H - h$. If the hydrostatic head H is drawn as a straight line, and the discharges in gallons per minute are platted as ordinates from the heights corresponding to the points of observation, and the extremities of these ordinates are connected, then will any ordinate to the curved line so formed represent the discharge at that height.

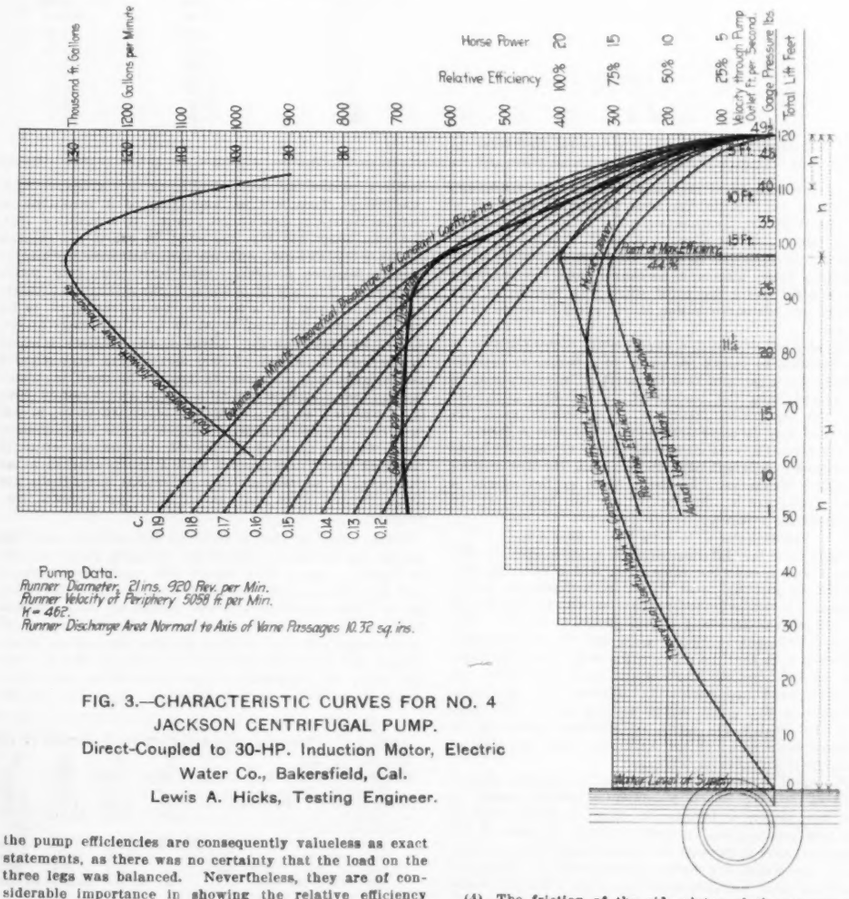


FIG. 3.—CHARACTERISTIC CURVES FOR NO. 4 JACKSON CENTRIFUGAL PUMP.
Direct-Coupled to 30-HP. Induction Motor, Electric Water Co., Bakersfield, Cal.
Lewis A. Hicks, Testing Engineer.

Consider the nature and magnitude of the friction resistances in a centrifugal pump with an enclosed runner. When maintaining a hydrostatic head without discharge, there are four principal sources of loss; namely:

(1) The slip or back circulation around the suction inlet caused by the leakage of water from the discharge under a head due the static lift. As ordinarily manufactured, with leakage on both sides of the runner, and an opening of $\frac{1}{32}$-in. around the suction inlet and balance ring, or when the bearings have worn slightly, this one item may account for 20% of the lost work. It evidently decreases with the height of lift.

(2) The frictional resistance of the circulated water across the side plates and through the vanes of the runner varying, approximately as the square of the velocity of flow, and as the flow is proportionate to the $\sqrt{h}$, this item also decreases with the lift.

(3) The drag of the runner periphery revolving at a high speed in water practically without velocity. The speed for the runner experimented with was 83 ft. per second. When discharge is taking place, the water in the throat and volute of the pump will attain a velocity proportionate to the area. Assuming, for instance, a velocity of flow of 15 ft. per sec. in the same direction as the runner, this loss would be decreased approximately in proportion as 68^2 is to 83^2, the difference representing about 40% of the original resistance. As this loss decreases with the increase in velocity of flow, it evidently decreases with the lift.

(4) The friction of the side plates of the runner with the water in the pump shell. Since this is independent of pressure, it will be a constant quantity for any height of lift.

When discharge commences, conditions are somewhat changed, since new elements of resistance are introduced. These are made up of the head necessary to create velocity of flow past the resistances offered by the pipes and pump passages, together with the kinetic energy lost in the form of discharge velocity. The sum of these resistances probably varies in a ratio somewhat less than the square of the velocity of flow, and therefore increases with a decrease in lift.

After discharge commences, it may be said in general that one source of lost work remains constant, three tend to decrease as the lift decreases and one increases as the lift decreases. A careful consideration of the relative value of each of the factors of resistance, with due appreciation of the relative unimportance of fluid friction at low velocities, would, it is thought, lead to the conclusion that as the lift decreases the decrease in friction would be in excess of the increase due to velocity. This would continue until the increasing velocity friction throttles the discharge so that it ceases to follow an ascending ratio of the available head. This point may be called the breaking down point of the pump, or the point at which the discharge commences to represent a smaller percentage of the theoretical flow due to the area and the head, supposing the algebraic sum of the resistances a constant. In

TABLE I.—SUMMARY OF TESTS OF CENTRIFUGAL PUMPS.

	1.	2.	3.	4.	5.	6.
Number of test						
Size of pump	No. 10 Vertical.		No. 12 Horizontal.	No. 8 Vertical		No. 8 Horiz
Connection	Direct.	Direct.	Belted.	Direct.	Direct.	Belted
Impeller (all enclosed)	18" enclosed open.†	18" enclsd contrctd	24" enclsd standrd	18" enclsd cont'd.	18" enclosed open.	24" enclsd st
Revolutions per minute: Motor	915	925	925	925	920	930
Revolutions per minute: Pump	915	925	546	925	920	549
Static lift: Suction, ft.	7.18	6.68	23.33	5.43	5.43	21.0
" Discharge, ft.	24.03	24.03	8.09	24.57	24.57	10.0
" Total, ft.	31.21	30.71	31.42	30.00	30.00	31.0
Gages: Vacuum, ins.	9	7.75	22	6	6.5	21.5
" Pressure, lbs.	12	11.46	5⅝	11	11.25	3.9
" Correction for position, ft.	—.13	—.13	—.50 + 2.17	—.50 + 1.08	—.50 + 1.08	—.33
Electric: Leg	A B C	A B C	A B C	A B C	A B C	A B
Electric: Watts	10,425 10,090 10,080	7,050 6,675 6,925	8,800 9,875 7,550	6,425 6,185 6,800	10,175 9,675 10,175	4,525 6,275
Discharge: Time, seconds	43⅝	67⅝	.....	64	41	.....
" Tank, gallons	1,878	1,878	.....	1,878	1,878	.....
" Leakage, gallons	27	34	.....	31	42	.....
" Weir	.....	.....	3³/₁₆×50 ins.	.....	.....	4⅝×50 in
" Total, gallons.	1,905	1,912	.....	1,909	1,920	.....
Pipe friction: Suction	2.98	2.07	1.59	1.36	1.93	3.27
" Discharge	3.51	2.20	6.62	1.12	1.93	0.75
" Total	6.49	4.27	8.21	2.48	3.86	4.02
Total equivalent lift, ft.	37.70	34.98	39.63	32.48	33.86	35.10
Discharge: Gallons per minute	2,621	1,697	1,831	1,790	2,810	1,380
Discharge: Cu. ft. per second	5.84	3.78	4.08	3.99	6.26	3.05
Pump velocities: Suction	5.36	3.47	5.19	3.66	5.74	5.59
" " Discharge	10.72	6.94	5.19	7.32	11.48	8.97
" " Periphery of impeller	71.82	72.65	57.17	72.65	72.26	57.50
" " $\sqrt{295}$	1.61	1.63	1.27	1.65	1.64	1.29
" " $6\sqrt{h}$	12.93	13.09	10.20	13.25	13.17	10.36
Pump input, mechanical HP.	36.92	24.63	32.51	23.16	30.22	10.32
" output, HP. due to static lift	29.71	18.19	14.57	13.60	21.30	10.77
" output, HP. due to total lift	25.02	15.03	18.37	14.73	24.09	12.16
" efficiency: Static lift	56.1	53.6	44.8*	58.7	58.8	*55.7
" efficiency: Total lift	67.8	61.0	56.5	63.6	66.5	62.9

*Throttled discharge. †Full peripheral discharge.

Fig. 3 the theoretical discharge for different coefficients in gallons per minute has been plotted as ordinates of the height of lift, and the variation in net resistance is clearly shown by the manner in which the line of actual discharge crosses the lines of constant resistance in an ascending ratio, attains a maximum, and then abruptly breaks down about the point where the velocity of flow through the discharge outlet of the pump becomes 15 ft. per sec.

You will notice that the experimental determination of flow amounts to rating the pump as a meter, so that the quantity being pumped into the main at any time may be ascertained from the reading of the pressure gage, and from the continuous record of an automatic gage, the daily flow may be computed with considerable accuracy.

If the discharge of a centrifugal pump at constant speed maintained a constant ratio to the head, the useful work performed would vary as the product of the weight of water discharged at any point into the height of lift. Expressed by formula,

$$\text{Useful work} = A \times c\sqrt{2gh} \times 62.5 \times h_1.$$

If the work for different heights is calculated by this formula and a constant value of c, and a curve is constructed by plotting these values as ordinates to a line representing the hydrostatic head, it will be found that this will always assume the form shown in Fig. 3. The height h increases as h_1 decreases, and the mathematical relation is such that the curve will always attain its maximum at ⅔H, the total hydrostatic head. and if the resistances were proportionately uniform the maximum efficiency of the pump would be attained at the same point. In practice the maximum efficiency occurs at the breaking down point of the discharge, when the ratio of discharge commences to decrease.

The actual work is shown in Fig. 3, together with a curve of relative efficiency which is plotted merely to show how closely it follows the curve of useful work in form and peculiarities. It seems evident, in view of this agreement, that if through favorable changes in the water ways of the pump, the discharge line could be maintained past the present breaking-down point, the efficiency would be very considerably improved. The actual efficiency may have been slightly more or less than shown, depending on how nearly the load was balanced in the three legs.

It is thought that the methods herein described offer a rational mode of investigating the so-called mysteries of the centrifugal pump, and that a wide range of observation along similar lines in the hands of competent designers may be expected to produce better pumps, which is the consideration that interests all of us. It is therefore with the idea of provoking discussion which may lead to a better understanding of the subject that the writer presents the tentative methods of analysis herein described.

Centrifugal pumps are commonly relegated to low lifts on the ground of inefficiency at high lifts. There appears to be no practical reason for this conclusion, and on the other hand the writer possesses experimental data which warrants the belief that efficiences of 70% to 75% may be reasonably specified and required for lifts of 100 ft. and over.

The length of time that this efficiency can be maintained in a given pump will depend on the amount of sand pumped, the excellence of the design and workmanship in the matter of minimizing back circulation and providing water-ways for low velocities, stiffer spindles, first-class bearings with self-oiling rings, a better grade of packing, and, finally, upon the ease with which the bearings are maintained and lubricated. The high speed of revolution makes it somewhat difficult to maintain packing successfully against vacuum pressure, but when purchasers demand a higher standard of excellence, and these matters receive the same intelligent care given to other machinery, there will be something of a revolution of opinion regarding centrifugal pumps. It is manifest from the tests submitted that the pump in use is not suitable for its work, and yet, with the low efficiencies shown, the results compare favorably with large high-duty plants elsewhere. The cost of pumping 1,000 gallons to a height of 100 ft. for fuel and attendance ranges from ½ ct. to 1¼ cts. for steam, and from ⅛ ct. to ⅜ ct. for water power. It will be seen from Fig. 3 that at the ordinary working pressure in the mains, 130,000 foot-gallons were pumped per kilowatt-hour. Assuming capital invested in transmission plant at $250 per HP., and a load factor of 50%, the probable cost per HP. to the consumer would be not far from $50 per annum, or about ¾ cts. per kilowatt-hour, making the cost per 100,000 foot-gallons about ⅝ ct. This could be improved with a pump adapted to its conditions to an average duty of 200,000 foot-gallons per kilowatt-hour, or at the rate of ⅜ ct. per 100,000 foot-gallons.

Where cheap current is available and suction conditions permit the setting, a centrifugal pumping plant suitable to supply a city of 5,000 people with motor, transformers and all equipment, including housing, can be installed for $2,500. This would provide two pumps set on a common base on either side of motor, to which they would be direct-connected, with suitable by-pass connections so arranged that ordinarily the delivery would be directly into the main, the peripheral runner speed being adapted to create 40 to 50 lbs. working pressure. In case of fire the opening and closing of a couple of valves would instantly run the pressure up to 100 lbs.

A duplicate plant could be installed for less than the ordinary investment in tank storage, and by leaving a pulley between the motor and pump, and a beltway to a gas or steam engine, the risk of interrupted service would be minimized. The consideration of relative first cost and fixed charges so created gives a yet more favorable showing. It is well known that the most economical pumping engine is not the one showing highest efficiency in terms of coal consumption, but that in which the sum of the fixed charges and coal cost is least.

The application of this philosophy to the centrifugal pump leads to the conclusion that a properly designed plant of this type in units up to 5,000,000 gallons capacity is economically superior to any other installation; and that where circumstances are favorable to the use of electricity, the simplicity, compactness and automatic regulation of these plants is unexcelled. Where steam is used, centrifugal pumps attaining an efficiency of 70% and connected to triple-expansion condensing engines capable of producing an indicated horse-power-hour with 15 lbs. of steam, may be expected to give a duty of 65,000,000 to 75,000,000 foot-pounds per 1,000 lbs. of steam, and, owing to the enormous difference in first cost, compare favorably in economic performance with high-duty machinery attaining a duty of 120,000,000 to 150,000,000 foot-pounds and a mechanical efficiency of 95%. These considerations must, in time, make the centrifugal pump an important factor in water-works service.

TABLE II.—Observed Data and Calculated Results of Test of No. 4 Centrifugal Pump for Electric Water Company.

Number of test	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12
Gages: Pressure, lbs.	*49½	44¾	40	35	30	25	20	15	10	7	24½	16
Vacuum, ins.	4	10	14	18¼	24	28	28	28	28	29	27	27
Static heads: Discharge, ft.	7.29	7.29	7.29	7.29	7.29	7.29	7.29	7.29	7.29	7.29	49.29†	30.29
Suction, ft.	5.50	9.33	12.66	17.00	19.33	21.25	21.42	21.42	21.58	21.75	20.83	20.83
Discharge valve: Opening, ins.	Closd.	20/80	33/80	41/80	46/80	52/80	58/80	67/80	80/80	293/80	293/80	293/80
Area, sq. ins.	....	1.70	3.09	4.02	4.71	5.28	6.03	7.11	9.64	26.97	26.97	26.97
Measuring tank: Time, secs.	....	374	264	202	156	154	135	145	142	147	140	150
Discharge, gallons.	....	12,655	15,324	16,628	16,054	17,174	15,342	16,470	16,189	16,612	15,820	16,680
Electrical measurements: Tachometer, revs. pr min.	935	930	930	930	930	920	920	920	920	920	930	920
Watts	17,000	20,220	22,474	25,053	26,044	28,765	27,685	26,493	24,781	23,650	28,190	26,788
Equivalent heads: Disch. ft.	115.33	104.42	93.42	82.00	70.42	59.00	47.33	35.92	24.42	17.42	57.75	37.92
Suction, ft.	4.50	11.33	15.83	20.92	27.16	31.70	31.70	31.70	31.70	32.83	30.58	30.58
Total lift, ft.	119.83	115.75	109.25	102.92	97.58	90.70	79.04	67.62	56.12	50.25	88.33	68.50
Friction heads: Discharge pipe, ft.	.....	0.62	1.75	3.30	5.00	5.70	6.00	6.00	6.10	5.99	7.75	7.50
Suction pipe, ft.	.....	0.12	0.55	0.66	1.00	1.14	1.20	1.20	1.22	1.18	1.08	1.08
Discharge elbow, ft.	.....	0.42	1.25	2.33	3.58	4.16	4.42	4.42	4.50	4.20	4.20	4.16
Suct'n elbows & f't valve.	.....	1.70	2.12	2.36	5.31	7.55	7.24	7.24	7.05	8.10	6.87	6.91
Veloc. & entrance h'd, ft.	.....	0.18	0.50	1.00	1.52	1.76	1.84	1.84	1.84	1.80	1.80	1.75
Valve, ft.	.....	96.09	83.12	69.08	54.54	41.83	29.62	18.20	6.50	0.00	0.00	0.00
Total, ft.	.....	99.12	89.29	78.62	70.96	62.16	50.33	38.92	27.25	21.20	18.33	17.50
Discharge: Cu. ft. per min.	.....	27.1	46.5	66.0	82.5	89.4	91.1	91.1	91.4	90.6	90.6	88.3
Gallons per minute.	.....	203.0	348.0	494.0	617	669	682	682	684	678	678	667
Velocity, ft. per second: Suction and discharge.	.....	2.30	3.95	5.61	7.01	7.60	7.74	7.74	7.77	7.70	7.70	7.50
Pump outlet, 4-in. diam.	.....	5.2	8.9	12.7	15.8	17.1	17.4	17.4	17.5	17.3	17.3	17.2
c‡	.....	.14	.16	.15	.18	.17	.15	.13	.12	.11	.16	.13
Watt HP.	24.00	27.11	30.13	33.59	35.71	38.56	37.11	35.51	33.22	31.70	37.79	35.91
Motor efficiency, %	80	80½	90	90	90	90	90	90	90	90	90	90
M. HP. delivered to pump	21.10	24.12	26.97	30.23	32.24	34.70	33.40	31.95	29.90	28.53	34.01	32.32
Pump: Water, HP.	00.00	5.94	9.62	12.85	15.25	15.35	13.64	11.67	9.71	8.62	15.16	11.58
Net efficiency, %	.....	24.33	35.57	42.54	47.45	44.24	40.84	36.57	32.47	30.21	44.54	35.83
Relative efficiency, %	.....	52.0	75.0	88.0	100.0	94.0	86.0	77.0	68.0	63.0	94.0	76.0

*Add 1.29 ft. distance from center of pressure gage to point where vacuum gage is connected.

†At 7 lbs. discharge pressure valve was wide open.

Note.—Observation Nos. 11 and 12 were made by increasing the static head with a vertical stand-pipe 42 ft. of additional length on No. 11, and 23 ft. on No. 12. These observations are intended to check Nos. 6 and 8 above, as to the comparative effect of discharge valve and stand-pipe.

‡Calculated for discharge pipe area and velocity; $c = \frac{D}{A \times \sqrt{2gh}}$. Note.—As electric measurements were only made on one leg, efficiencies are probably in error, but relative efficiencies would be about correct, assuming maximum efficiency realized as 100%. Assuming the correctness of efficiencies as shown, the delivery into mains at working pressures ranges from 100,000 to 130,000 ft.-gallons per K-W. hour.

Pump was direct-connected to horizontal shaft. motor.

Fig. 7. Proposed Section.

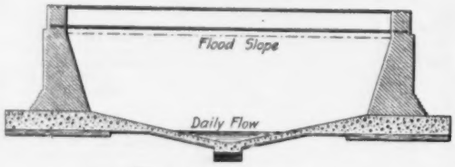


Fig. 8. Modified Section.

FIGS. 7 AND 8.—SECTIONS OF MAIN CANAL AS FIRST PROPOSED IN 1895, AND AS MODIFIED BY THE DRAINAGE COMMISSION FOR FINAL CONSTRUCTION.

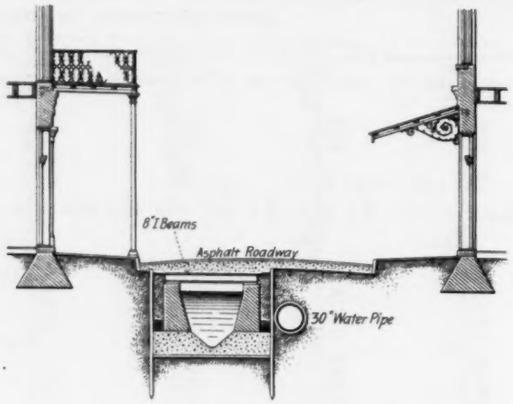


FIG. 10.—CROSS-SECTION OF CHARTRES ST. CANAL; A TYPICAL MINIMUM SECTION.

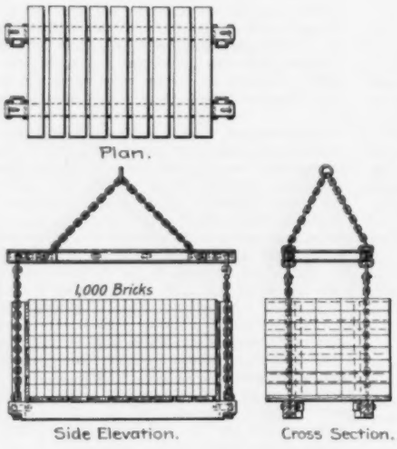


FIG. 17.—CRATES FOR HANDLING BRICKS.

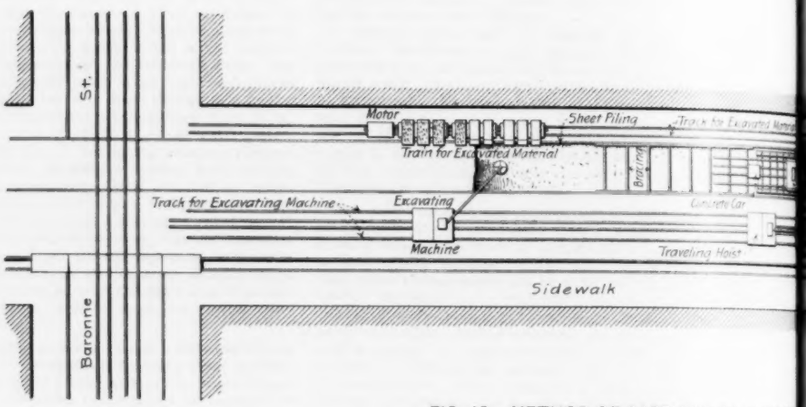


FIG. 12.—METHOD OF CARRYING ON WORK ON JULIA ST.

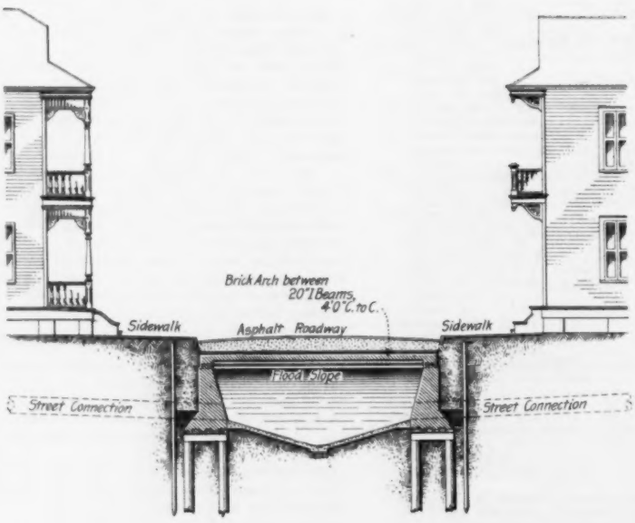


FIG. 9.—CROSS-SECTION OF ST. LOUIS ST. CANAL; A TYPICAL MAXIMUM SECTION.

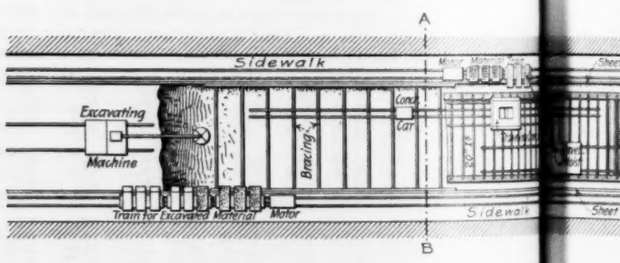
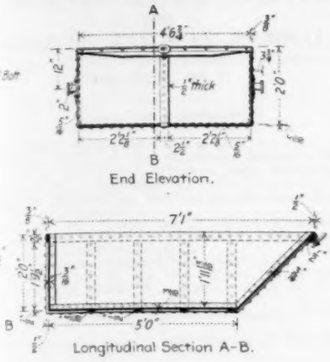
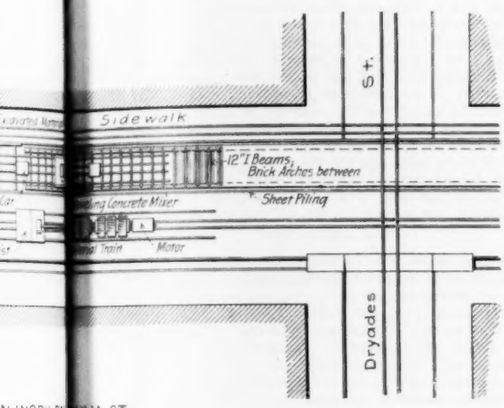


FIG. 11.—ARRANGEMENT OF MACHINERY AND METHOD OF CONSTRUCTING ST. LOUIS ST. CANAL.

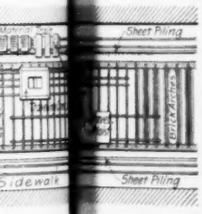
THE DRAINAGE OF THE CITY OF NEW ORLEANS



14.—STEEL SKIPS FOR HANDLING EXCAVATED MATERIAL.



N WORK ON JULIA ST.



MACHINERY
ST. LOUIS ST. CANAL.

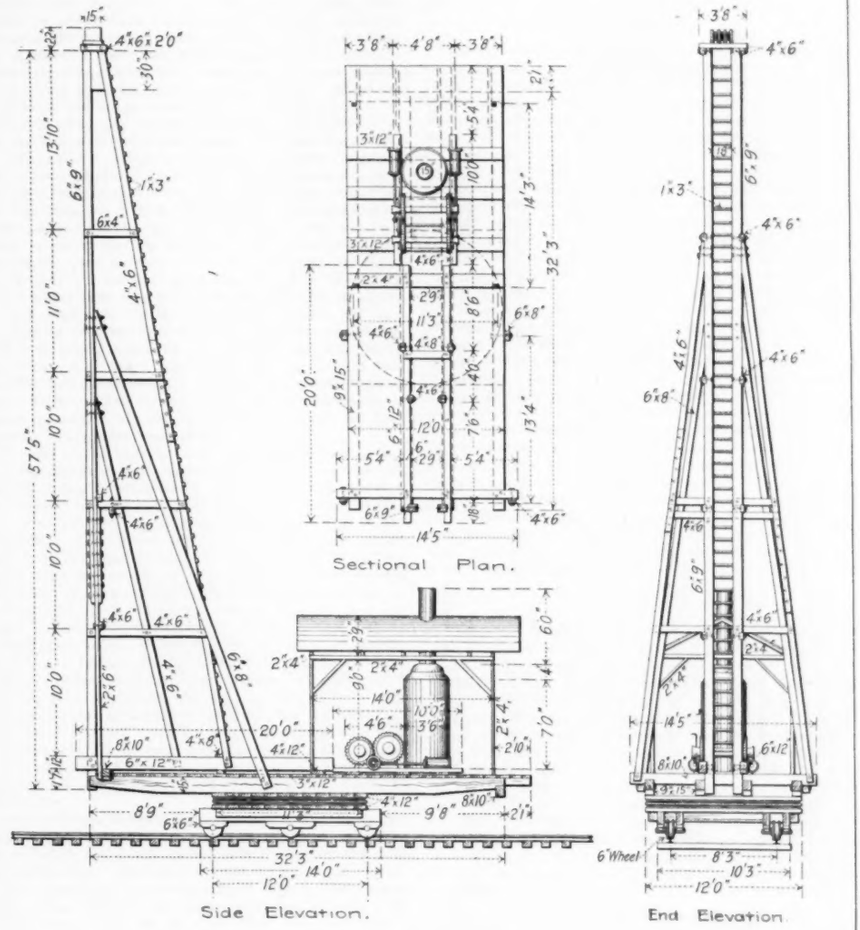


FIG. 13.—TURN-TABLE PILE-DRIVER FOR NO. 2 HAMMER.

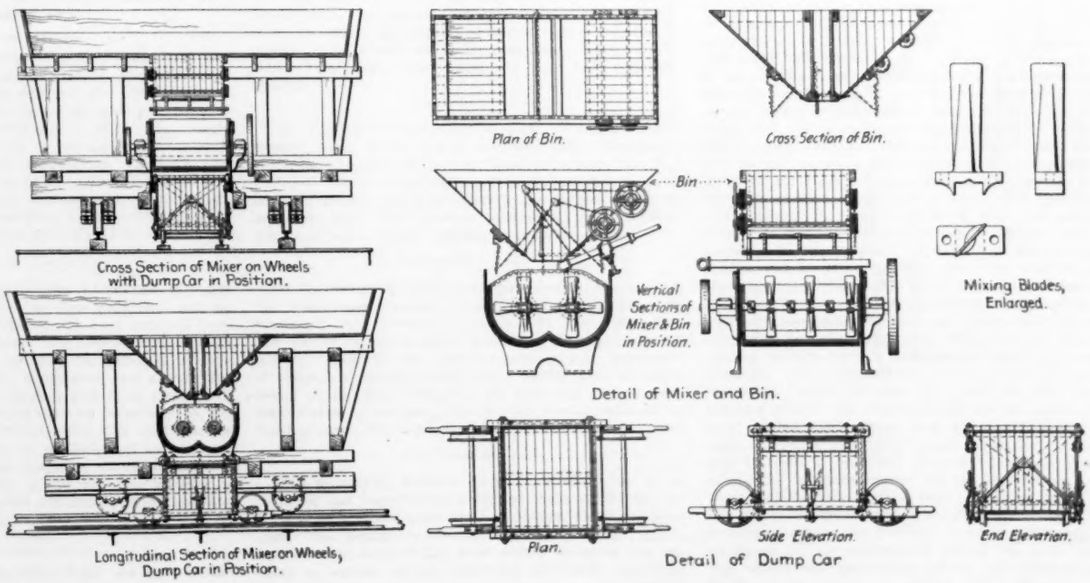

Cross Section of Mixer on Wheels with Dump Car in Position.
Longitudinal Section of Mixer on Wheels, Dump Car in Position.
Plan of Bin.
Cross Section of Bin.
Bin
Vertical Sections of Mixer & Bin in Position.
Detail of Mixer and Bin.
Mixing Blades, Enlarged.
Plan.
Side Elevation.
End Elevation.
Detail of Dump Car

FIG. 16.—CONCRETE MIXER, MATERIAL BINS AND DUMPING CAR.